Computerized Conceptual-Cost-Estimating System for Domestic Water Supply Projects

by

Mashhoor Dawood Al-Asfoor

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

June, 1993

Order Number 1355309

Computerized conceptual-cost-estimating system for domestic water supply projects

Al-asfoor, Mashhoor Dawood Hamza, M.S.

King Fahd University of Petroleum and Minerals (Saudi Arabia), 1993

COMPUTERIZED CONCEPTUAL-COST-ESTIMATING SYSTEM FOR DOMESTIC WATER SUPPLY PROJECTS

BY

MASHHOOR DAWOOD AL-ASFOOR

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING

AND MANAGEMENT

JUNE, 1993

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
DHAHRAN 31261, SAUDI ARABIA

COLLEGE OF GRADUATE STUDIES

This thesis, written by **MASHHOOR DAWOOD AL-ASFOOR** under the direction of his Thesis Advisor and approved by his Thesis Committee, has been presented to and accepted by the Dean of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING AND MANAGEMENT.**

THESIS COMMITTEE

Dr. Sadi Assaf (Chairman)

Dr. Mohammed Al-khalil (Member)

Dr. Walid Abdurrehman (Member)

Dr. Abdulla Al-sukairi (Member)

27/6/93.
Department Chairman

Dean, College of Graduate Studies

28th of June 1993
Date

DEDICATED TO MY BELOVED PARENTS,
TO MY WIFE AND CHILDREN,
AND TO MY SISTERS

ACKNOWLEDGMENT

Acknowledgment is due to the Ministry of Electricity and Water in the Sultanate of Oman and due to King Fahd University of Petroleum and Minerals for support of this research.

I wish to express my appreciation to Doctor Sadi Assaf who served as my major advisor and who provided me excellent guidance and support. I ,also, wish to thank the other members of my Thesis Committee, Doctor Mohammed Al-Kahalil from the Department of Construction Engineering and Management, for his guidance and in- depth discussion on the subject of cost estimation; Doctor Walid Abdurrehman from the Research Institute for his valuable help on the subject of water engineering; and Doctor Abdulla Al-Sukairi from the Department of Information and Computer Science, for his outstanding support on the computer-related issues. All of the above have been an excellent asset to this research.

I express my special gratitude and will remain ever in debt to my father, Dawood and my mother, Khadija who made exceptional efforts in making my childhood happy and my future bright. I, also, express my deep and sincere appreciation to my wife for her kindness, understanding, unlimited patience, and generous support throughout the long years of my studies. Thanks to my sons, Haidar, Ahmad, and Hussain for giving me enjoyment and laughs during the difficult time of this research. I am particularly grateful to my sisters for their encouragement, support, and continual reassurance that enabled me in accomplishing my goals.

Special thanks to His Excellency Mohammed bin Ali Al-Qatbi, minister of Electricity and Water in Oman for his support and encouragement to my master studies.

The efforts of senior management, middle management, and engineers of the Ministry of Electricity and Water are sincerely appreciated. Thank them for their guidance, support, and the provision of necessary information.

Thanks to Mott McDonald International Ltd., for the data and important literature they provided to me. Thanks to Mr. Robert Hilden, English Language Center, KFUPM, for his valuable effort and time spent to edit this manuscript. Thanks to my friend Mr. Mahmood Al-Akram, MBA program, KFUPM, who facilitated my communication with the Thesis Committee during my research work in Oman. Thanks to my cousin Alaa Al-Rahma for his generous help, support, and care.

THESIS ABSTRACT

FULL NAME	Mashhoor Dawood Hamza Al-asfoor.
TITLE OF STUDY	Computerized Conceptual Cost Estimating System for Domestic Water Supply Projects.
MAJOR FIELD	Construction Engineering and Management.
DATE OF DEGREE	June, 1993.

Large funds are expended on domestic water supply projects; however, lack of appropriate conceptual cost estimating techniques causes difficulties such as project delays and cost overruns. This thesis presents a structured and systematic procedure for the implementation of a Computerized Conceptual Cost Estimating System (CCES) for Domestic Water Supply Projects. CCES has been designed to produce cost estimates at the conceptual stage when only a little information is available about the project.

The research began with the identification of the factors influencing the costs of pipeline, reservoir, and pumping station projects. Next, historical cost data of commissioned projects were gathered from tender documents and subsequent regression analysis was carried out. The regression analysis was computer-based which facilitated a "what-if" analysis during the model creation course and helped examine the adequacy of the cost factors. Moreover, the adequacies of the cost models were checked and found to comply with the standards of the American Society of Cost Engineers. Finally, the cost models were integrated into a user-friendly application software.

This thesis demonstrated that a well thought-out integration among the science of cost estimation, statistical analysis, and computer technology enhances the practices of cost estimating. Although the research focused on the Sultanate of Oman as a case study, the methodology set forth is relevant to the construction and water industries in general, particularly in the Arabian Gulf countries.

MASTER OF SCIENCE DEGREE

KING FAHD UNIVERSITY OF PETROLEUM MINERALS
Dhahran, Saudi Arabia

JUNE, 1993

خلاصة الرساله

اسم الطالـــب: مشهور بن داود بن حمزه العصفور
عنوان الدراسه: نظام كمبيوتري للتقدير المبدئي لتكلفة مشروعات المياه
التخصـــــص: هندسة و ادارة التشييد
تاريخ الشهـاده: يونيو - ١٩٩٣م

ان مشروعات المياه تستهلك موارد ماليه ضخمه بشكل دوري الا ان عدم وجود طريقه علميه صحيحه لتقدير التكلفه المبدئيه لهذه المشروعات يؤدي الى صعوبات كتأخر المشروع و تجاوزه للميزانيه المرصوده. لذلك ناقشت هذه الرساله الخطوات العلميه المنهجيه لتطوير نظام للتقدير المبدئي لتكلفة مشروعات المياه بواسطة الحاسب الآلي. و قد روعي في تصميم هذا النظام قدرته على التنبؤ بتكلفة المشروع في مراحله الأوليه في الوقت الذي لا يعرف عن المشروع الا معلومات مقتضبه و ذلك تسهيلا لعملية اتخاذ القرارات المبكره المتعلقه بالموازنه و التمويل و ادارة المشروع.

و الأطروحه تبدء في مرحلتها الأولى بتعريف العوامل المؤثره في تكلفة مشروعات انابيب المياه و الخزانات و محطات الضخ. و على ضوء نتائج هذه المرحله تم تجميع بيانات التكلفه من مستندا ت مناقصات المشروعات التي نفذت سابقا و تم الاءستفاده من هذه البيانات كمعطيات للتحليل الاءرتدادي الاءحصائي لتطوير نماذج رياضيه. و قد تم استخدام الحاسب الآلي في عملية التحليل مما ساعد في وضع سيناريوهات مختلفه لغرض اختيار عوامل التكلفه الملائمه و المؤثره في النماذج الرياضيه. و عند اختبار هذه النماذج الرياضيه المطوره و جدت مطابقه لمواصفات الجمعيه الأمريكيه لمهندسي التكلفه. و في نهاية البحث ، ادمجت نماذج التكلفه ببرنامج كمبيوتري تمت برمجته ضمن هذا البحث للحصول على نظام متكامل و سهل الاءستخدام لتقدير تكلفة مشروعات المياه.

ان هذه الرساله قد اثبتت ان التكامل بين علوم هندسة و ادارة التشييد من جهه و التحليل الاءحصائي و الحاسب الآلي من جهة اخرى يعزز و يسهم في تطوير الأساليب و الممارسات المتبعه في هندسة و ادارة التشييد. و بالرغم ان هذه الرساله كشفت البحث على سلطنة عمان الا ان خطواتها المنهجيه تسهم بشكل ايجابي في صناعتي التشييد و المياه و خصوصا في دول مجلس التعاون الخليجي.

<u>درجة الماجستير في العلوم</u>

جامعة الملك فهد للبترول و المعادن
الظهران - المملكه العربيه السعوديه
يونيو - ١٩٩٣م

TABLE OF CONTENTS

Page

Page

Page

LIST OF ABBREVIATIONS

AACE: American Association of Cost Engineers
AAER: Average Annual Escalation Rate
AC: Asbestos Cement
A/E: Architecture/Engineering Consulting Professional
BOQ: Bill of Quantities
CCES: Computerized Cost Estimating System
CER: Cost Estimating Relationship
DGW: Directorate General of Water
DI: Ductile Iron
DIA: Diameter Variable
DIA_SQR: Square of Diameter
DUR: Duration Variable
Hr: Hour
Km: Kilometer
m: Meter
MAE: Mean Absolute Error
MEW: Ministry of Electricity and Water
MFE: Ministry of Finance and Economy
MID_CNGSTN: Moderate Congestion Variable
MMI: Mott McDonald International
NO_CNGSTN: No Congestion Variable
OR: Omani Riyal
O_U: Over-Under Variable
O_U_MDFD: Modified Over-Under Variable
PC: Personal Computer
ROAD_XING: Variable Representing Length of Pipe Crossing a Road
SE: Standard Error
TRANS: A Dummy Variable Representing Pipeline Scheme (Transmission=1 Distribution=0)
WADI_XING: Variable Representing Length of Pipe Crossing a Wadi Valley)
WRC: Water Research Center

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 CONCEPTUAL COST ESTIMATING

Conceptual Cost Estimating is a vital tool for construction developers. It is necessary for planning, budgeting, funding, construction management, and the quality of the end product. The purpose of conceptual estimates is to produce as accurate an estimate as possible with very limited information. No detailed drawings or specifications are required for conceptual estimates; instead, a general conception of the project's characteristics such as size and location. In fact, conceptual cost estimating system facilitates early decision-making and judgment within the project development cycle.

Historical cost data of commissioned construction projects is the "raw input" for any realistic cost estimate. Conscious construction organizations make effort to collect and store cost data for the uses of future decision-making. However, construction costs, like the costs of other commodities, fluctuates over time due to many factors such as inflation and the market environment. Thus, cost data needs to be adjusted for such factors before using it as input for any cost estimating method.

The computer can play an important role in the preparation of a conceptual estimate. Over the last few years, the capabilities of minicomputers have increased substantially and their prices have dropped. This has opened the way for the automation of cost estimating and construction management practices. In fact, automated estimating systems have been used for some time. Such estimating systems have been historically limited to mainframes or large minicomputer systems. However, a PC-based conceptual estimating system that statistically analyze historical cost data is the focus of this research .

1.2 WATER IN THE ARABIAN GULF COUNTRIES

Water is one of the most important and precious resources and its presence secures the presence of life. Based on this fact, we realize the importance of efforts invested toward preserving, managing, and controlling this resource on our planet. Indeed, proper water management and planning becomes critically important in arid areas such as the Arabian Gulf countries where quantities of water are limited. Moreover, intelligent water planning and management are indispensable in these countries as the demand for water is continuously increasing because of the accelerating rates of industrial development and economic international interests.

1.3 DISCUSSION ON THE PROBLEM

1.3.1 DESCRIPTION OF THE PROBLEM:

In developed and developing countries large funds are expended on domestic water supply projects. In the Arabian Gulf countries such as the Sultanate of Oman and Kingdom of Saudi Arabia, where water is a precious resource, billions of dollars are expended in water related projects. However, lack of appropriate conceptual cost estimating techniques causes project delays and cost overruns. This research will focus on the problem in the Sultanate of Oman as a case study; however, the profile of this study should be relevant to neighboring countries of the Gulf.

In the Sultanate of Oman, the Ministry of Electricity and Water (MEW) is the governmental agency responsible for supplying potable water to the public and industry. Every year, millions of Omani Riyals (OR) ($1 ≈ OR 0.38) are expended on the construction of water projects to meet the increasing demand in different regions of the Sultanate. These expenditures are attributed to the following [**Omani-American Joint Commission, 1986]:**

1) Improving water supply systems in large cities to meet the increasing demand. Table 1.1 shows typical projects for water supply improvement.

2) Construction of new water supply systems in newly developed areas. The projects shown in table 1.2 represent typical examples.

Hence, developing a reliable conceptual cost estimating tool is of a considerable importance for the MEW as the utilization of such tool can save the government a considerable amount of money by improving the reliability of budgeting, planning, project management, thereby producing a quality end product. For instance, the delay in the completion of the Seeb Overhead Water Tank Project (1989), was caused by the absence of a reliable conceptual cost estimating procedure. The initial cost of this project was estimated to be RO 0.3 million and , correspondingly, a similar budget was allocated; however, the lowest bid turned out to be RO 0.7 million: 133 % more than the estimated cost. At that time, the MEW had two choices: to wait another 2 year period to arrange the budget as part of the next five year plan, or redesign the project and cut off more than 50 % of its requirements in order to reduce its cost. Clearly, both "solutions" contain implicit problems which could have been avoided had the cost estimate been more accurate.

TABLE 1.1 Typical Projects of Water Supply Improvement

Project Name	Cost (Million RO)	Status
Improvement of Muscat Water Supply	13	Under construction
Alamirat Water Supply	3.5	Under construction
Alqurum/14 Water Supply	0.3	Commissioned

Table 1.2 Typical Projects of New Water Supply Systems

Project Name	Cost (Million RO)	Status
Sur Water Supply	2	Under construction
Nizwa Water Supply	2	Commissioned
Rustaq Water Supply	1.5	Under construction

1.3.2 PROBLEM STATEMENT:

Sufficient cost data of completed projects is available from the MEW; yet, it is scattered and difficult to retrieve when required. So, the cost estimating of new projects is performed on a subjective basis rather than proven methods. This current situation introduces the following problems:

1) Cost data is mismanaged leading to non-utilization of the data; and hence, a valuable source of information is wasted.

2) The accuracy of cost estimates is seriously jeopardized by the judgment of the estimator.

3) The required time for the estimate may considerably be longer if accuracy is to be achieved.

4) The cost estimating job is limited to a few senior engineers only.

1.3.3 APPROACH TO THE PROBLEM:

A variety of reliable conceptual cost estimating methods are used in the construction industry; however, selecting the most suitable method for the construction of water projects and developing it into a computerized model will yield a more reliable and a faster estimation tool.

Therefore, it is proposed to develop a Computerized Conceptual Cost Estimating System (CCES) based on statistical analysis of historical cost data. CCES should be capable of estimating the costs of urban water supply projects within an acceptable range of accuracy. Moreover, it should produce such an estimate when only little information is available about the project during the conceptual phase. Indeed, the CCES can be implemented when the intermediate objectives of this study are achieved. Those objectives are discussed in detail elsewhere in this chapter.

1.4 NEED FOR RESEARCH

Domestic water supply projects are among the basic infrastructure projects which the national plans is addressing, hence, a considerable portion of the national investment is poured into water supply projects. Oman is a typical country of the Arabian Peninsula where water resources are limited, thus, funds allocated for developing water services should be properly planned in order to produce the maximum yield. Therefore, developing a science-based conceptual cost estimating system for domestic water supply projects will considerably enhance the planning and project management in the MEW.

Moreover, a water project follows certain procedures before it is commissioned. In the conceptual stage, budget has to be allocated from the Ministry of Finance and Economy (MFE) upon the request of the MEW. In this stage, an order of magnitude cost estimate serves as a justification for the MEW's request. Later on, the MEW appropriates this budget to the proposed project before the design and construction start. The Same reasoning is applied when the Water Project Department requests a budget from the Financial Department within the MEW itself. Moreover, a reliable cost estimate serves as a "bench mark" to the designer so the quality and size of the project are designed within the estimated cost.

1.5 OBJECTIVES OF THE STUDY

The main objective of the study is to develop a Computerized Cost Estimating System (CCES) which is capable of estimating the cost of future projects for domestic water supply based on previous cost data. The following are the intermediate objectives:

1) Identification of cost determinant factors (cost drivers).
2) Collection of historical cost data.

3) Development of cost models.

4) Computerization of cost models.

5) Validation of the computerized cost models.

1.6 RESEARCH PARAMETERS

1.6.1 SCOPE:

This research shall only focus on DOMESTIC WATER SUPPLY PROJECTS in the Sultanate of Oman as a case study and shall address the MEW cost estimating function. However, it can be used as a guide to develop conceptual cost estimating systems in the other Arabian Gulf countries.

1.6.2 LIMITATIONS:

The following types of water supply projects only have been considered:

i. Reservoirs.

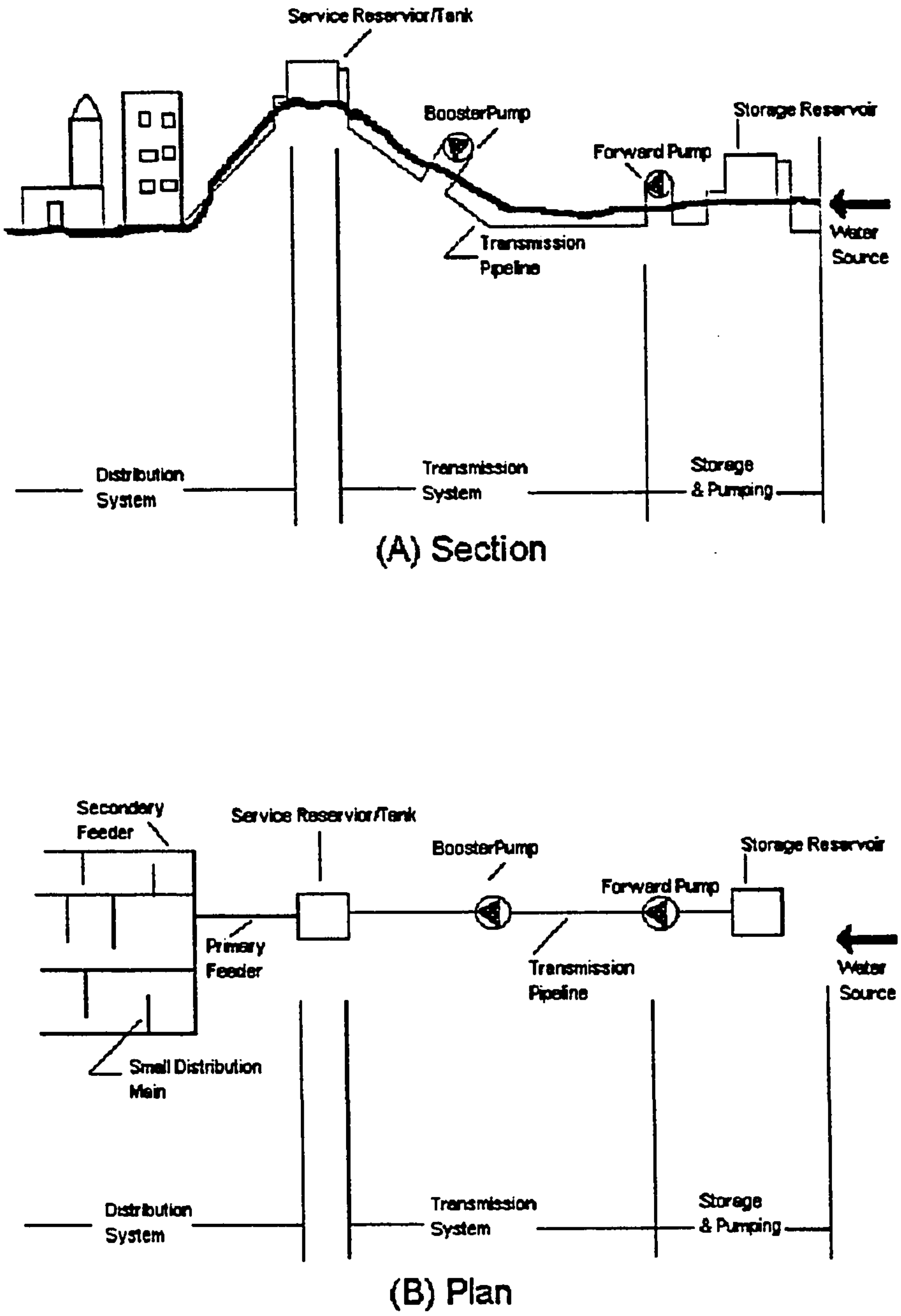

Figure 1.1 Schematic Diagrams Illustrating Water Supply Projects

1.6.4 ISSUES TO BE CONSIDERED:

To make the CCES a versatile system; the following issues have been observed:

1. CCES should be expandable to cover other water supply projects.

2. CCES should be adaptable for more enhanced features.

3. Local prevailing conditions in the Sultanate of Oman and the Gulf region should be considered when reviewing the international cost estimation methods.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 CONSTRICTION COST ESTIMATING

Until the early nineteenth century rough cost forecasting satisfied the society's needs fairly adequately: most building projects were undertaken either as an act of religious faith or by the very rich for their own pleasure, and in both cases the necessary resources were likely to be thought of at the end. However, upon the significant economical advancement caused by the Industrial Revolution, people in the construction industry started appreciating the importance of cost estimating. This appreciation resulted when those people realized the importance of optimizing the use of the scarce resources **[Ferry and Brandon, 1991].** Frank Borman, the first human to orbit the moon said:

> "earth's material resources are limited and that the use of these resources must be planned and controlled carefully in order to ensure our continued survival on this planet. We are like someone stranded on a desert island with a limited amount of food or an

> airplane pilot lost over the ocean with a limited amount of fuel. Each must estimate and plan consumption of the most valuable resource based on the time or distance to be covered and the quantity of the resource available. The solutions to either of these problems of scarce or limited resources require the best possible estimate of future occurrences" **[Stewart, 1991].**

Truly, in the world of the modern construction industry, cost estimating is considered one of the major pillars upon which the industry is depending. Indeed, the success or failure of a construction project is dependent in great measure on the accuracy of several major estimates, including the project owner's feasibility estimate, the conceptual design estimate, and on the contractor's detailed bid estimate.

Construction cost estimates are distinct in nature from others in the sense that each construction project is unique in its characteristics; thus, an inherent uncertainty exists in any cost estimate whatsoever. On the other hand, many other manufacturers, because of long production runs are able to determine product cost by actual calculation from cost data collected as the product is built and subsequently priced **[Akeel, 1989].**

An estimate is, by definition, a forecast of future events, and because of the uncertainties of the future, construction estimating will never be totally scientific. Instead, the preparation of accurate construction estimate is partly a science and partly an art **[Adrian 1982].**

There are several cost estimating methods that have been created by research and validated by construction experience. The method used is constrained by the degree of definition of the information on which the estimate is based. This information varies as the project advances, being sparse in early stages and voluminous in later stages **[Hackney, 1992].**

2.2 TYPES OF CONSTRUCTION COST ESTIMATES

Construction cost is the cost incurred by the construction activities only and does not include the costs of the A/E's supervision. The American Association of Cost Engineers (AACE) classified the various capital cost estimates according to the following classifications **[Manzanera, 1991]:**

o Order of magnitude estimates
o Preliminary estimates
o Definitive estimates

2.2.1 ORDER OF MAGNITUDE ESTIMATE:

Also called a "conceptual estimate", this type of estimate is practiced by owners after the mental definition of the project has been clarified. All it takes is a general conception of the project in terms of size, materials, construction method, and quality [Collier 1984]. There are two objectives for this estimate: first, to assess the survival potential of the project (Feasibility), and second, to aid the owner in obtaining funds for the project. (Funding). According to the AACE, the following is applicable to this type of estimate:

- Accuracy range	- (-30% to +30%)
- Required information:	- Capacity
	- Location
	- Utility requirements
	- Service requirements
	- Building requirements
	- Raw materials and storage requirements
	- Finished product and its storage requirements

Methods falling under this type of estimate will be discussed thoroughly later in this chapter as the proposed CCES will be an Order of Magnitude Estimate.

2.2.2 PRELIMINARY ESTIMATE:

When the project is found to possessing a good chance of success, the owner engages an A/E firm to determine all of the design aspects of the project. Based upon the prepared plans and specifications, a more accurate estimate can be prepared by the A/E or a specialized estimating firm. The main objectives of this estimate is to support the owners feasibility estimate, to evaluate possible design modifications in order to meet the owners budget, to evaluate contractors' bids, and as an aid in budgeting cash flow needs throughout the project. According to the AACE, the following is applicable to this type of estimate **[Manzanera, 1991]**:

- Accuracy range - (-15% to +30%)
- Required information:
    - Site description, surveys and soil studies
    - Process flow sheets
    - Engineering specifications
    - Preliminary structural design
    - Preliminary architectural design
    - Preliminary construction plan
    - Rough insulation specification
    - Preliminary motor list and sizes

- Substation specifications
- Preliminary lighting specifications
- Engineering and drafting man-hours

2.2.3 DEFINITIVE ESTIMATE:

After designing and specifying the project on documents, the owner procures the construction services via a contracting firm. In order to perform a proper bid estimate, contractors usually request all relevant documents such as project drawings, specifications, general conditions of contract, agreements, and addenda. However, the most important documents used to prepare bid prices are the drawings and specifications as the drawings reveal the quantity of work to be performed, whereas, the specifications indicates the targeted quality. The purpose of the definitive estimate is to determine the real cost of the project. It worth mentioning here that this type of estimate is more widely known as "Bid Estimate" and "Detailed Estimate". "We may realistically typify bid estimates as the only true estimates and all other kinds of estimates as simulations" **[Collier 1984]**.

The definitive estimate usually includes the estimated cost of the project in addition to the contractor's desired profit. The key operation in this type of estimate is the quantity take-off of the work items. Thus, contractor should make the minimum assumptions as possible, and use as much relevant information as available to minimize the risk. Finally, the objective of a contractor bidding on a project is to get the job of building the project (being the low bidder), and still maintains acceptable amount of profit [Akeel 1989]. According to the AACE, the following is applicable to this type of estimate [Manzanera, 1991]:

- Accuracy range - (-5% to +15%)
- Required information:
  - Full site information
  - Process flow sheet
  - Equipment vessels specifications and Engineering arrangements
  - Detailed engineering and structures drawings
  - Insulation drawings and specifications
  - Electrical installations drawings and specifications
  - Utility installation drawings and specifications
  - Man-hours calculations for engineering, drafting, labor, and supervision.

2.3 ORDER OF MAGNITUDE ESTIMATE

"Conceptual estimate" is a relatively new term, and was officially recognized in 1975, when an American federal government publication stated that construction managers needed more expertise in "conceptual estimating" [Akeel, 1989]. The word "conceptual" indicates that this category of estimates is to serve the purpose of cost estimating when the project is no more than a "concept" in the mind of the developer; hence, the relevant information of the project is in an abstract form. There is, therefore, an obvious need to use a method which can process this "little" information and still produce an acceptable accuracy **[Ferry and Brandon, 1991].**

AACE further classifies the conceptual estimating methods as described in the following sections.

2.3.1 COST ESTIMATING RELATIONSHIPS FOR PROJECT UNITS:

Cost Estimating Relationship (CER) is a relationship represented in the form of charts or formulas relating costs for complete project "units" to single or multiple cost parameters, based on collected data for past projects. Usually, these are referred to as "project-unit cost curves". Relevant CERs are adjusted to a specific base date and place for consistency, and to make adjustments for inflation. The famous methods of Unit-Cost Estimate and Parameter-Cost Estimate are classified within this type **[Hackney, 1992]**.

2.3.1.1 UNIT-COST ESTIMATE:

This technique is based on the fact that there is usually a close relationship between the cost of a project and the number of functional units it accommodates. Functional units are those factors which express the intended use of the project better than any other. For example, it may be the number of students in a school, the number of vehicle spaces in a car park, the number of theater seats, or the number of kilometers of a pipe line **[Ferry and Brandon, 1991]**.

In establishing a preliminary cost estimate by means of a function estimate, the estimator is expected to know or approximate the cost per functional element. Multiplying this cost times the quantity of the functional elements yields the total cost estimate.

For example, suppose a pipe line for a distance of 30 kilometers has recently been constructed for the sum of RO 600,000. The cost per kilometer of the pipe line would obviously be:

RO 600,000/30 = RO 20,000

If a pipeline with a similar parameter is to be laid for a length of 20 kilometers , then it might reasonably be assumed that the cost would be:

20 x RO 20,000 = RO 400,000

under the assumption that all other things are being equal.

Unfortunately, in reality all things are rarely equal and consequently a number of judgments must be made about prevailing price levels due to the market conditions, inflation effect, site difficulties, specification changes, and other factors. Hence, to arrive at a reliable cost estimate, the estimator has to adjust for such factors **[Kemner and Abraham, 1987]**.

2.3.1.2 PARAMETER ESTIMATE:

In general, the accuracy of a pre-design estimate improves as the number of project characteristics included in developing the estimate increases. Parameter cost estimating is a method that predicts the cost of a project in terms of a number of project's characteristics or "parameters". **[Karshenas and Yousuf, 1985]**.

The parameter cost estimate method was proposed by McNulty and subsequently published by Engineering News Record in 1966 **[Karshenas and Yousof, 1985; Akeel, 1989]**. Parameter estimating is basically a less aggregated Unit-Cost estimate which takes into consideration multiple cost parameters rather than a single parameter. The underlying idea of this estimating technique is to relate all costs of a project to a few physical measures or parameters that reflect the size or scope of the project. Parameter estimating is mostly used to estimate costs of buildings because buildings contain more parameters than heavy and highway projects. It is important to note that a preliminary sketch of the building is required to facilitate the computation of parameters such as gross enclosed area, roof area, area of face brick, total basement floor area, and HVAC tonnage. After computing the controlling parameters of the project, a historical cost data for the same parameters and from a similar project are multiplied by the quantities of the corresponding parameters to yield the cost of each parameter. Adding the costs of all parameters would yield the total cost of the project **[Adrian, 1982]**.

2.3.2 EQUIPMENT CERs WITH FACTOR RATIOS:

Equipment CERs are similar to project unit CERs, but deal with single pieces of equipment and usually are referred to as "equipment cost curves". They are used to estimate equipment costs to which factor ratios are applied to determine the cost of other factors of the estimate, such as piping, instruments, and engineering. Again, it is essential to maintain both cost curves and factor ratios as a base date time and place [Hackney, 1992]. The following described methods are classified under Equipment CERs with Factor Ratios.

2.3.2.1 FACTOR ESTIMATE:

Even though factor estimating can be used to estimate various types of projects, it is best used for projects with a major component having the greatest impact upon the project's cost. Often this component is the purchased equipment for the building [Akeel, 1989]. Examples of such projects are process plants such as oil refineries and foundries; also, costs of pumping stations and water desalination plants can be estimated with a factor estimate.

In order to prepare a conceptual estimate for a project using the factor method, the cost of the predominant item should be quoted and given a factor of 1, then multiplied by factors associated with other components of the project [Suarez, 1986]. Assuming that reliability of the historical cost data and the components have the same cost relationship to the basic cost item as in previous projects, then the estimate is fairly reliable.

In the water industry, the cost of pumping stations can be reliably estimated using the factor estimating technique. Usually, the cost component of the pumps dominates over the individual cost components of the housing structure, electrical installations, and other items of the pumping station. In this case, the cost of the pumps is given a factor of 1, whereas the cost of housing structure, for instance, is given a factor of 0.7: indicating that the cost of the housing structure is 70% of the pumps' cost. Same proportioning is applied for the costs of the other components which might be given factors of 0.4 for the electrical installation, 0.3 for the crane, and so on. When the cost for a new pumping station is to be estimated, a bid for the pumps has to be acquired from the vendor, then the structure cost is 70% of the pumps' cost, the electrical installation cost is 40% of the pumps' cost, and so on. Adding all these costs together, would give the total cost of the proposed pumping station.

2.3.2.2 EQUIPMENT COST BY SCALING:

Equipment cost by scaling is also called cost capacity factor. The words "equipment" and "capacity" reveal the scope within which this method is most appropriately used: with projects of productive equipment. "Although, the Equipment Cost by Scaling is only a generality, its prevalence is a powerful factor in the economics of continuous process operations" [Hackney, 1992]. In order to estimate the cost of a plant, for example, this method uses historical data of a similar plant, but it takes into consideration the difference in capacity.

The following formula represents the nonlinear relationship between the cost and the capacity of the project:

$$Cp = Ce * (Qp/Qe)^{x}$$

where,

Cp: Total cost of proposed facility

Ce: Total cost of a similar existing facility

Qp: Capacity of the proposed facility

Qe: Capacity of the existing facility

x : Cost Capacity factor appropriate for the type of facility; usually about 0.6 to 0.95 (i.e. for petrochemical sector; x=0.6)

2.3.3 COMPOUND CERs:

Multiple parameter CER is a technique for estimating costs from the physical and/or performance characteristics of the subject under consideration, regardless of the magnitude of the aggregated systems involved. It is also called "statistical and parametric estimating" and was developed in the 1960's to meet the rapidly changing technologies and performance of the aerospace industry [Manzanera, 1991]. Moreover, this method was practically introduced to the construction industry by mid 1970's and was characterized by the intensive use of regression analysis. The popularity of this technique appeared to increase in direct relationship to the growth in availability and reduction in the cost of microcomputers [Raftery, 1987]. It involves collecting and organizing historical cost data about the cost driving parameters and relating this cost data, through mathematical techniques, to the cost of the project being estimated. The general form of the compound CER model is as follows:

$$Cost = C + (B1*V1) + (B2*V2) + \ldots\ldots + (Bn*Vn)$$

where,

C: Constant which represents a cost measure of the project.

Vn: Variable number n which is influencing the cost such as the material of a pipeline.

Bn: Associated constant of variable n [Raftery, 1987].

AACE provides the following procedural technique to construct a reliable compound CER model:

1. Problem definition:

To determine the objectives and scope of the whole exercise.

2. Data collection:

This step relates to historical cost information and how it may be collected. Data collection must be planned according to specific needs and parametric definitions.

3. Data normalization:

All collected data must be adjusted for:

- Time
- Size
- Inflation
- Technological advance
- Learning process
- Productivity
- Social activity and the like.

All data gathered must be subject to consistent definitions to avoid redundant information or confusion.

4. Cost drivers identification:

Identification of project characteristics that are most directly related to its cost.

5. Cost estimating relationship:

Once all cost drivers are identified, a relationship or interdependency may be developed by means of regression analysis **[Manzanera, 1991]**.

The Water Research Center (WRC) in the United Kingdom carried out a study to produce cost functions for major construction items in water and sewage services to be used at the national planning level. The WRC study was characterized by the intensive use of compound CER techniques, which is in line with the methodology of this research. A major finding of the WRC study was the provision of a mechanism to account for variables (cost factors) known to be important but they could not demonstrate statistical impacts upon the cost models. Accordingly, engineering attitude was used as the basis of a more intuitive approach to provide Over-Under (O-U) factor. Contributory cost drivers making up the O-U factor were identified, and to each of these was attached a series of possible weightings, or scores. The sum of these scores for a contract forms the value of the O-U factor, which is an attempt to measure the tendency of a contract to be difficult or easy, and hence whether it is likely to be cheaper or more expensive than the average **[WRC, 1977]**.

2.4 OTHER TYPES OF COST ESTIMATES

2.4.1 RANGE ESTIMATING:

Uncertainty is a major characteristic of any cost estimate; however, range estimating could address this uncertainty and hence considered a complimentary technique for any cost estimating method **[Mlakar and Bryant, 1990]**. The uncertainty of a particular cost estimate is a function of the estimator's experience, characteristics of the project, and the timing of the estimate. Hence, range estimating recognizes and evaluates this uncertainty in an attempt to present a more realistic cost estimate.

Probability theory is heavily used to establish the lowest, highest, and the most probable cost of a project. Practically, the relatively tedious computations involved make it difficult to be handled manually. However, computer programs have been developed to assist the user of the range estimating method [Adrian, 1982].

2.5 COMPUTERS AND CONSTRUCTION

Historically, computers have been viewed by the construction practitioners as accounting machines. Much of their utilization has been in the applications concerning the payroll, accounts payable, and overall general ledger accounting functions. Yet, over the decade of the eighties, computers have taken more crucial roles in the construction industry [Collier, 1987]. However, the advancement of computer technology is surprisingly fast and the utilization of computers in the construction industry is still lagging and sub optimum

2.5.1 COMPUTERS AND ESTIMATING:

Computers, coupled with the appropriate software and estimating skills, can increase the speed and accuracy of the estimating process. Estimates prepared using computers are less likely to contain errors, hence, this accuracy results in increased profitability. That is, increasing the productivity in the estimating process reduces overhead costs , bid costs, and bidding times, and subsequently increasing the profit margin.

Computers can help estimators at various stages of the estimate preparation. Semi-automated quantity take-off, providing data from files of past projects, and assist with specialized engineering software in calculations such as earth moving fleet simulation, and formwork calculations, are vivid examples where estimators can substantially benefit from the power of computers [Akeel 1989].

2.5.2 ARTIFICIAL INTELLIGENCE (AI):

Since the first commercial computer appeared in 1950, researchers have studied AI in an effort to create a machine that can simulate the thinking processes of the human mind. Recently, they have found that the thinking processes of the human mind are far more complex than had previously been recognized. Recent development, however, are changing this purely theoretical approach. The area of Knowledge Based Expert System (KBES), a subcategorey of AI, offers great promise for productive applications in the field of cost engineering **[Rounds, 1986].**

People involved in the cost engineering field realize that "expert" cost estimators are very scarce. Hence, simulating the "knowledge" and "expertise" of those experts by a machine would substantially alleviates the problem: that is the objective of applying KBES in the cost engineering. Ntuen and Mallik (1987) explained the objectives of the KBES by saying "an expert system embodies in a computer the knowledge- based components of an expert skill in such a form that the system can offer intelligent advice, and on demand, justify its own line of reasoning".

Utilization of KBES in cost engineering is still in its infancy; however, it is the "tool" of the near future for the field of cost engineering as well as for other engineering and managerial disciplines **[Rounds, 1986].**

2.6 STATISTICAL BACKGROUND

The cost functions used in this thesis have been derived empirically using statistical methods. In normal cases the actual data shows a certain degree of scatter (lack of fitness) about the fitted cost function. It is particularly important that these obvious uncertainties are expressed in an objective and unambiguous manner, and this can only be done in statistical language. The following is a brief background of statistical terms and nomenclature **[WRC, 1977 and Albright, 1987]**.

2.6.1 STATISTICAL DEFINITIONS:

The following are definitions for the statistical terms frequently used in this manuscript:

A) Variable: A measurable factor of interest (e.g. cost of a project, capacity of a reservoir, etc.).

B) Data, Sample: The starting point of a statistical study; the collected values of all variables under consideration.

C) Population: The entire set of possible values of a variable (e.g. the capacity of all pumping stations in Oman).

D) Statistic: Any summary measure calculated from a data sample, like sample mean or standard deviation.

E) Mean: A statistic which locates the "center" value of the sample.

F) Standard Deviation (σ): The most commonly used measure of 'spread'. For a normally distributed variable; roughly 95% of the values in a sample will lie within two standard deviations of the mean. The square of the standard deviation is known as the variance.

G) Outlier: An extreme data value suspiciously far away from other members of the sample.

H) Confidence Interval: A statistical device which gives information on how far the true mean of a particular statistic is from the sample mean.

I) Function, Model: Terms used interchangeably in this manuscript to mean a statistically derived relationship relating one variable (usually cost) to other explanatory variables.

J) Simple Regression: A statistical technique for deriving a model by relating the cost, for example, to just one explanatory variable.

K) Multiple Regression: An extension of simple regression to deal with more than one explanatory variable.

L) Regression Coefficient: The calculated numerical values in a regression equation (e.g. Cost = 12.3 + 4.5*Capacity; the regression coefficients for the cost model are 12.3 and 4.5).

M) Parameter: Numerical values of a measure relating to an underlying population.

N) Standard Error: A term preferred to standard deviation, though meaning exactly the same, when referring to uncertainties in an estimate of a population parameter.

O) Significance: The essence of statistics is to use the information in a sample to make inferences about the underlying population. A particular variable can only be rejected as unlikely to represent the population if it is statistically significant at a particular level, say 5%. In hypothesis testing, that variable has a real effect on the model when it is rejected at 5% level.

P) F-statistic: Calculated when testing the significance of a regression model. The larger the F-statistic , the more representative is the model.

Q) Correlation Coefficient(R): A quantity which indicates the overall goodness of fit of a regression model. It lies between -1 and +1. The closer the value to zero, the lower is the correlation; an R of +1 or -1 indicates a perfect fit.

R) Coefficient of Determination (R^2): The square of the correlation coefficient. It lies between 0 and 1, and measures the proportion of the original variance which is explained by the regression model.

S) Normal Distribution: A symmetrical bell-shaped distribution of great importance in statistical theory.

T) Dummy Variable: A variable that indicates the category a given observation is in. It is usually coded to have values 0 or 1.

U) Durbin-Watson Statistic: A statistic to detect autocorrelation and have a value from 0 to 4. If it is close enough to 2, then there is no evidence of autocorrelation.

V) Autocorrelation: When errors in the sample are independent, the regression model does not experience autocorrelation.

W) ANOVA: Analysis Of Variance, used to test the significance of a linear relationship in the regression model as a whole.

CHAPTER 3

MODELING

3.1 GENERAL

Cost Estimating Models have different levels; for instance, suppose a model is required to estimate the capital cost of a pipeline project. At the simplest level, the model might simply relate the total cost to the population to be served. Such a "global" model could only be expected to give a rough estimate, satisfying the need for broad planning purposes. Alternatively, the model might consist of a collection of sub-models or "building bricks", each predicting the cost of separate processes or components within the works. This would yield a more precise forecast in return for a more detailed specification of the projected works. The model would therefore be of interest to planners at design or contracting level, whereas its greater detail might be irrelevant to the regional or national planner.

The variety of possible models which could be constructed for a particular area can be visualized as a hierarchy of models. Moving down the hierarchy, total cost is successively broken down into more detailed constituents, each of which is separately modeled. The object of moving down a level is to gain precision or flexibility, but this potential benefit must be weighed against the following considerations:

i) Is the data available at this level?

ii) How much effort is needed to assemble it ?

iii) Are the models likely to improve very much?

iv) Who is going to be interested in models at this level ?

v) Will the user have the necessary input when he wants to use the models ?

The answers to these questions varies widely from area to area. As a general rule, the approach was to begin at the top of the hierarchy by building a simple global model, and to descend to more detailed sub-models only if this seemed worthwhile and the global model fell short of the desired accuracy.

The ultimate objective of this thesis is to develop cost models to be used as order of magnitude estimates at the conceptual stage of the project when hardly any detailed information is available. Hence, no consideration has been given to break down the cost models to lower levels.

Although the end results of this study addresses the cost modeling issue in the water and construction industries in general and particularly in the Arabian Gulf countries, a special focus was made on Oman. Thus, key administration and technical members of the DGW in Oman were exposed to this study and were asked to participate in the various stages of this research. As an initial step, the thesis topic was presented to the following key persons in the DGW:

1) H.E. The Director General of Water
2) Director of Water Projects
3) Chief Engineer of Water Projects
4) Senior and Junior Water Project Engineers
5) Chief Engineer for Operation and Maintenance

In addition, DGW's main consultants and contractors were informed and copies of the thesis proposal were submitted to them and subsequent discussions were carried out.

In order to facilitate proper planning and easier progress throughout, the research task was broken down into the following work packages:

1) Identification of Cost Determinant Factors (section 3.2)
2) Data Collection (section 3.3)
3) Development of Cost Models (section 3.4)
4) Computerization (chapter 4)

5) Validation of Cost Models (chapter 5)

3.2 IDENTIFICATION OF COST DETERMINANT FACTORS

The cost of any construction project is a function of several factors (cost drivers) as previously discussed in the literature review. In this step, tender documents for the completed water projects under consideration were analyzed and reviewed with the objective of determining those influencing factors. In addition, a close consultation was carried out with the Project Engineering Department of the MEW and the main MEW's consultants such as Mott McDonald International Ltd.. Also, the literature of international studies was reviewed and taken into consideration when identifying those factors.

3.2.1 COMMON FACTORS:

There are some cost determinant factors which are common to all types of construction projects and are often related to the cost incurred by the general preparation and preliminaries (mobilization & demobilization) and site subsoil condition rather than the specific characteristics of the project. The following factors were found to be common and thought to have certain impacts upon the cost of any project:

A) LOCATION OF THE PROJECT:

When the project is located away from the contractor's base, there are two cost items that have to be added to the bid, namely, transportation and temporary camp-establishment costs. As the contractor has to transport the necessary resources (equipment, labor, and materials) to the location of the project, hence, transportation cost is directly proportional to the distance from the contractor's base to the location of the project. Moreover, in case the project is located thousands of kilometers into the desert, the contractor does not have the flexibility of transferring his resources from that project when they are not in need and, hence, the resources remain idle at a cost burdening the bid price. The magnitude of this factor is expressed in KILOMETERS representing the distance between the contractor's base and the project's location.

B) DURATION OF THE PROJECT:

This factor is having an impact upon the unit price of any project as described below:

i) Longer Duration ⟶ Larger Project ⟶ Lower Unit Price

Larger projects tend to have lower unit prices because the project's fixed cost is spread over a larger quantity of units

ii) Longer Duration ⟶ Less Urgent ⟶ Lower Unit Price

Hence, the longer the duration of a project the lower its unit rate. The magnitude of this factor is expressed in MONTHS.

C) EXPECTED LIFE OF THE PROJECT:

Long-lasting projects cost more than those of shorter life. In Oman all domestic water supply projects were constructed for a standard period of time. Hence, this factor was not included in the study as the data sample experience no variation.

D) MARKET ENVIRONMENT:

During flourishing periods in the economy, demand for services, including construction, increases; this demand drops when the economy undergoes a recession. Correspondingly, similar fluctuation take place with the prices of services governed by the supply and demand forces in the market. For instance, during the recession periods contractors are willing to bid with lower profit margins for the sake of covering their running costs. Nevertheless, this factor was excluded from this study because no data was readily available to measure its magnitude.

E) GRADE OF CONTRACTOR:

Contractors ranked in higher grades tend to bid higher than those with lower grades. Construction practitioners believe that the following reasons are behind this fact:

i) Higher grade contractors professionally manage the project execution.

ii) Higher grade contractors are more financially stable and, hence ,can stand behind their contractual obligations easily.

iii) Higher grade contractors possess more resources and, hence, are expected to produce a better end product.

iv) Higher grade contractors have more survival potential and, hence, are expected to provide a better After-Sale-Service.

Generally, higher grade contractors provide better construction services and, consequently, cost more than those with lower grades who maintain inferior construction standards [Akeel, 1987].

In our case this factor was excluded because the DGW limits the bidding opportunity to the excellent grade contractors only and, hence, no variation can be detected by the model. In addition, information about this factor was not available for some projects.

F) GENERAL VICINITY OF SITE:

The vicinity of the site affects the project's cost associated with:

i) Accessibility: Projects located in easily accessible sites cost less than those with difficult accessibility such as mountainous sites.

ii) Restrictions on site operations: Projects located in a highly restricted areas tend to be more expensive as the contractor's equipment find difficulties when maneuvering around or when handling materials. A crowded urban area is a vivid example of such a restricted area.

WRC's findings, previously discussed in section 2.3.3, were adopted for this study, with minor modifications, as those findings were solely based upon the engineering characteristics of the projects, and hence, applicable to countries other than Britain. For more details refer to section 3.4.2.1.

G) GROUND CONDITION:

Primarily, the cost of excavation depends upon the softness/hardness of the subsoil stratas. Harder types, like rock, costs more because it takes more time to excavate, needs more expensive equipment which gets severely and quickly deteriorated by rock. Also, the magnitude of this factor was measured with the WRC findings.

H) SPECIAL FEATURES:

Projects with special features such as remote control devices, electronic monitoring systems, and automation cost more than those with conventional arrangements. However, this factor was excluded from our study because the majority of water projects in Oman are conventional.

3.2.2 PIPELINE COST FACTORS:

The following cost determinant factors are applicable to pipeline projects only:

A) DIAMETER:

There is a proportional and nonlinear relationship between the cost of a pipe's section and its diameter. This non linearity is attributed to the nonlinear increases in the section's area and wall thickness when the diameter increases. This relationship has to be accounted for when developing the model.

B) MATERIAL OF PIPES:

Different pipe material are specified for different uses. For example, Ductile Iron (DI) is used primarily for high pressure sections such as transmission lines and distribution networks located in high pressure zones whereas Asbestos Cement an PVC pipes are more often used for low pressure sections. Hence, associated differences in costs should be depicted in the cost model.

C) TRENCHLESS CROSSING:

It is required by Omani municipalities to use a pipe jacking technique (thrust boring) when laying the pipeline across the road or a public highway to prevent traffic congestion and pavement cutting. Trenchless crossing costs more than average pipe laying as it requires special equipment, special supervision, and consumes more time.

D) WADI PROTECTION:

The wadi (valley) channel is an outstanding feature of Oman's topography. It guides the surface runoff to the ocean during the rainy season, a natural flood protection system. When a pipeline crosses a Wadi channel, special protection is required as stated by the MEW's water works standards. This protection is achieved by embedding the pipeline section into a concrete rectangular casing across the width of the Wadi. Obviously, this arrangement costs more than the average pipe laying, which needs to be accounted for especially when a significant length of the pipeline crosses Wadis.

E) TERRAIN:

Laying a pipeline in a hilly area, necessitates trenching different depths along the route; hence, increasing the complexity of the scheme which necessities a variety of excavation and pipe-handling techniques. Moreover, the resulting peaks and valleys along the pipeline profile necessitate more fittings like bends, air valves and associated concrete chambers.

F) DIAMETER RANGE:

Diversity of diameters might indicate an increase in complexity of the scheme; hence, the project's cost has more potential to increase.

G) TYPE OF SCHEME:

There are two different types of pipeline projects being constructed by the DGW in Oman, namely, transmission and distribution. Usually, the transmission is laid in a single line route with no branching. On the other hand, the distribution is more complex in terms of branching and junctions. When more junctions are introduced into the pipeline system, more fittings will be required and pipe laying becomes more tedious. As a rule of thumb, fittings for a transmission pipeline cost about 10% of the pipeline's cost, whereas 20% is normal in the case of a distribution network. However, this study only considers transmission mains and distribution feeders. Distribution feeders, sometimes called arterial, assemble the skeleton of the distribution system. They carry large quantities of water to the various areas to be served and they do not involve extensive branching [Steel and McGhee, 1977].

H) PRESSURE RATING:

Pipes which could sustain higher working pressures cost more than those built for lower working pressure. However, this factor was excluded from our pipeline model because all pipes in Oman are standard in term of pressure rating.

I) ENVIRONMENTAL CONSIDERATION:

Pipelines laid in an aggressive environment need special protection such as, cathodic protection, bitumen coating, or polythene sleeving. However, this factor was excluded from our pipeline model because all pipes in Oman are similar in term of environmental protection standard. MEW requires the pipeline to be coated with a Bitumen and inserted in Polythene Sleeves.

3.2.3 RESERVOIR COST FACTORS:

The following cost determinant factors are applicable to reservoir projects only:

A) STORAGE CAPACITY:

The bigger the capacity, the larger the reservoir; hence, the more expensive it is.

B) SHAPE OF RESERVOIR:

Covered storage tanks for treated water can be of three principal types: rectangular, circular, or overhead. The cost of each differs in response to its unique structural system and construction methods. However, this factor was excluded from the reservoir model because no circular and only a few overhead tanks have been ever built in Oman, the data of which could not have been retrieved, limiting the study to the rectangular tanks only.

C) MATERIAL:

Reservoirs are made of different materials such as concrete, steel, and fiberglass, and their costs vary widely. Correspondingly, the installation costs associated with a particular material also vary.

3.2.4 PUMPING STATION COST FACTORS:

A) PUMPING CAPACITY:

Higher pumping capacities (m^3/Hr) require bigger pumps and their associated motors, ancillaries, and installation, all of which increase cost.

B) INSTALLED NUMBER OF PUMPS:

Usually, in most pumping stations, one or more pumps are additionally installed as "standbys" to replace out-of-order pumps in case of emergency. Hence, more installed pumps results in higher costs.

C) THE PUMP'S HEAD:

When water is pumped to high elevations and/or to remote points downstream, the pump's output pressure (head) must be sufficient to drive the water against the diverse potential energy and head losses due to friction between water molecules and the inner surface of the conduit. Pumps with higher heads cost more than those with lower heads; hence, this variation should be addressed when estimating the cost of a pumping station.

D) CRANE CAPACITY:

In any pumping house, a crane must be installed. This crane is used to install and remove pumps and motors during the maintenance course. Cranes with larger carrying capacities cost more. Moreover, the crane's cost is significant with respect to the total cost of the pumping station; therefore, requires consideration when estimating the cost of a pumping station.

3.3 DATA COLLECTION

3.3.1 GENERAL

Originally, final account costs rather than tender figures were to be used in this study. However, the first attempt toward data collection showed that detailed final accounts were not available, so it was decided that successful tender figures would suffice for the following reasons:

1) In most cases, the final account is within ± 5% of the tender price as reported by the Chief Engineer of Water Projects (MEW) and Mott McDonald International Ltd., (main consulting firm for water supply projects in Oman). Generally, this is sufficiently adequate for establishing an order of magnitude

estimate as specified by the AACE.

2) Final costs would often be more difficult to relate to a specific date for inflation adjustment than would tender costs.

Therefore, all of the results are based solely on accepted tender documents. Each tender document contains a bill of quantities (BOQ) out of which the cost data of each project was retrieved.

In order to initiate the data collection, it was necessary to establish the cost of each case in the data sample. In the simplest modeling areas, the BOQs refer to just one item, such as a pipeline or a reservoir. Often, however, the BOQs for one contract might refer to a number of different major structural items of interest, and it was necessary to identify the costs relating to each individual item. This was, generally, complicated by the presence of costs additional to those specific to the items of interest. Those common costs are associated with the general provision of work items as required by the "Standard Condition of Contract for Civil Engineering and Buildings," like "General and Preliminaries," "Daywork," and "Provisional Amounts," are typical examples of common cost items. They were, therefore, assumed to be proportional to the costs of each item. Figure 3.1 shows a simplified example illustrating the distribution of common costs. Consequently, the cost to be used for developing each cost model was adjusted proportionally to take into account the effect of those common costs. Moreover, a contingency amount

SUMMARY OF "BOQ"

Bill #	Title	Amount (RO)
1	General and Preliminaries	50,000
2	Daywork	20,000
3	Pumping Station	200,000
4	Transmission Main	150,000
	Subtotal	420,000
	Add 5% Contingencies	21,000
	Total	441,000

Proportion of Pumping Station Cost = 200,000/(200,000+150,000) = 0.57

Total Cost of Pumping Station = [200,000+0.57(50,000+20,000)]*1.05
= RO 251,895

Total Cost of Transmission Main =[150,000+0.43(50,000+20,000)]*1.05
= RO 189,105

Figure 3.1 Simplified Example Illustrating the Distribution of Common Costs of Historical Cost Data.

for each observational project expressed as a percentage of total cost of work items was added to form the total bid cost. It should also be noted that some observational projects contained "special requirements" which had cost implications, the cost associated with those special requirements have been excluded from the total work items.

3.3.2 AVAILABILITY OF DATA:

Original plan was to collect data from the MEW's records; however, because of the poor filing and archiving system, the researcher was unable to retrieve a single observational project other than those currently under construction. At that moment, MMI consulting firm was approached and was able to provide the majority

The majority of domestic water supply projects are pipelines, hence, a reasonable number of observational pipeline projects have been located (33 observations). On the other hand, the number of reservoir projects ever constructed in Oman is much fewer than the number of the pipeline projects. There are 19 reservoirs known to have been constructed out of which the researcher was able to locate tender documents for 12. Finally, the number of pumping station projects, unfortunately, was even fewer and the researcher was not able to locate more than 6 observations. Therefore, the adequacy of the reservoir and pumping station cost models needs to be diagnosed and checked seriously via the available statistical tools . Also, to achieve maximum reliability of the model in such cases, the number of explanatory variables should be kept as low as possible (Albright, 1987 and Stanton, 1989).

Secondary sources of information included various technical journals, contractors, and vendors. Moreover, the Development Council (A governmental organization responsible for preparing master development plans for Oman) was the prime source for the various indices used to normalize the data.

3.3.3 NORMALIZATION OF DATA:

The collected historical cost data was produced in the period from 1979 up to 1992, during which costs nearly doubled through inflation and other factors. Therefore, the importance of correcting costs for the effect of the escalation is much greater than before when escalation was running at slower pace. The purpose of normalizing the data for the effect of escalation is to relate the costs of all projects to a common time reference and adjust the costs of all projects as if they were tendered at that time. The Development Council in Oman annually publishes price indices for different commodities and services. These indices were adopted to normalize the prices of pipes and general construction, the bar charts of which are shown in figures 3.2 and 3.3. Simple inspection of these bar charts reveals that the trend of prices was increasing throughout the period of 1974 to 1992. The average annual escalation rates (AAER) are the slopes of the dotted lines located more or less halfway between the "peaks" and "valleys" of the bar charts. The AAER's for pipes and general construction were determined to be 5% and 1.5% respectively. Those rates were confirmed by the Quantity Surveying Department of Petroleum Development Oman (PDO) and main suppliers of pipes and equipment, Almuttawah Trading Company and Amianttet Oman, who reported an AAER of 5% for equipment, fittings, and valves as well. On the other hand, AAER was found to be 1.5% for pipe laying and was determined by reviewing tender documents, discussions with consultants, contractors, and with staff of the Water Project Department in the DGW. Table 3.3 exhibits the AAERs used to normalize the data for this study. The following formula was used to adjust the historical cost data to January 1993.

$$\text{Cost}_{(\text{January 1993})} = \text{Cost}_{(\text{Project's Date})} * [\, 1 + i/100 \,]^{n}$$

where,

i: annual escalation rate of prices (%) since the project's date to January 1993.

n: Time difference between the project's date and January 1993 calculated as follows:

$$n = [1993 - \text{Project's Year}] + [(\text{Project's Month} - 1) / 12]$$

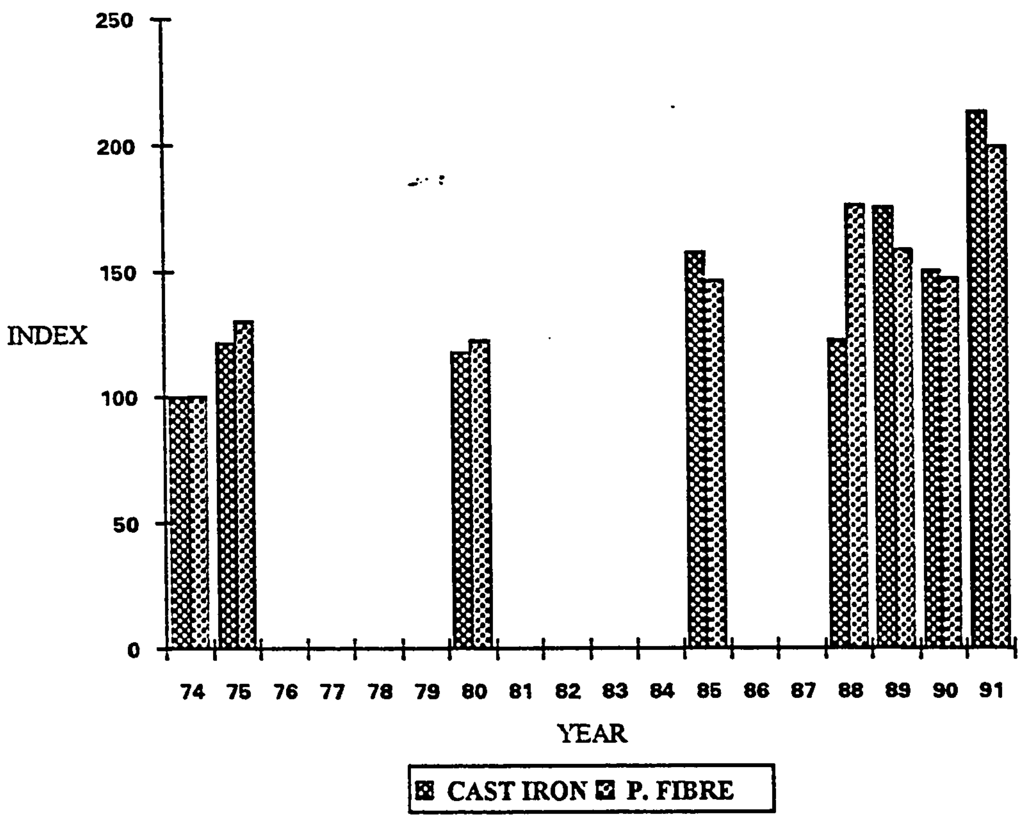

Figure 3.2 Price Index of Pipes

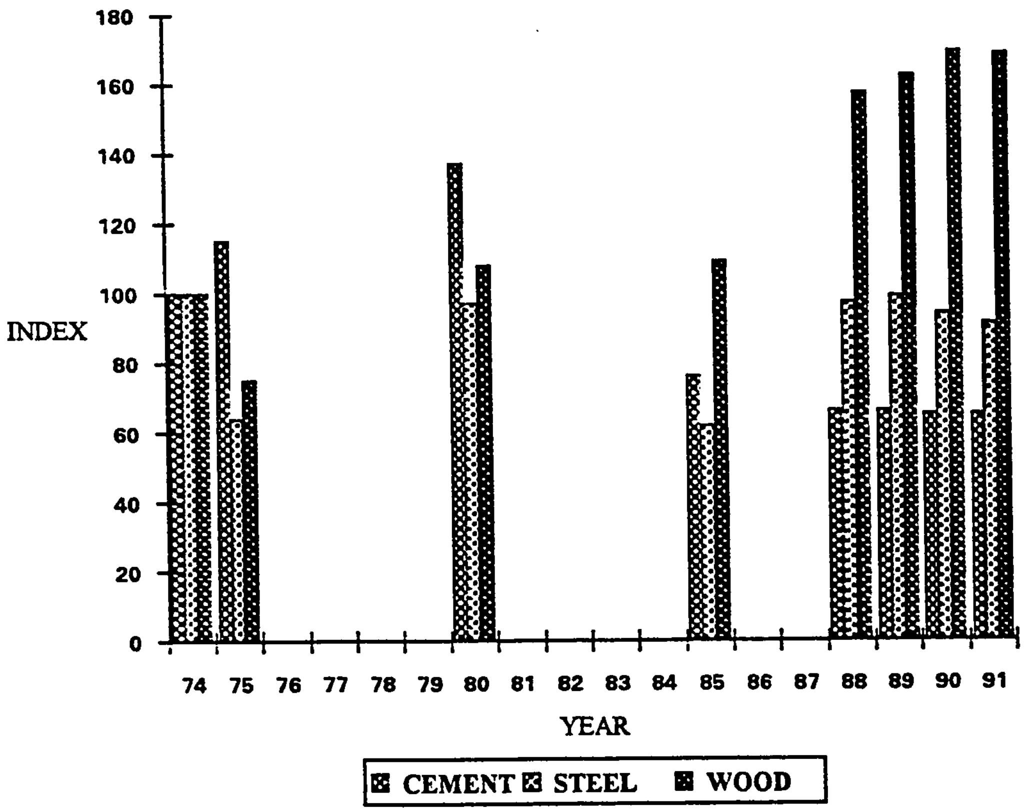

Figure 3.3 Price Index of Basic Materials for General Construction

Table 3.3 Average Annual Escalation Factors in Oman

ITEM	ANNUAL ESCALATION FACTOR	SOURCE
Pipes, Fittings, Valves, and Equipment	5%	Development Council Petroleum Development - Oman Almuttawah Trading Company Amianttet Oman
Pipeline Installation	1.5%	Examination of Tender Documents. Interviews with Consultants and Contractors.
General Construction	1.5%	Development Council

3.4 DEVELOPMENT OF COST MODELS

3.4.1 GENERAL

The statistical analysis of past experience to predict the future is one of the basic cost estimating functions. Completed project costs can be analyzed by statistical techniques to serve in variety of ways. In the areas of estimating, probably the most widely discussed and used statistical tool is multiple regression analysis. By examining historical data through multiple regression analysis, functional relationships can be developed for use in the estimating process.

The statistical technique of multiple regression allows the derivation of cost equations or models having one or more variables (**Albright, 1987**). The variables used in the analysis are a combination of objective and subjective variables. Objective variables are those that can be derived directly from the data, such as the diameter of a pipeline, the capacity of a pumping station, and the storing capacity of a reservoir. Subjective variables, however, are the ones which do not have direct measurements, such as the general vicinity of site and complexity of the project. In any case, all variables to be used in the regression analysis must be quantified. The analyst must find a way to convert all subjective variables to numbers.

Regression analysis involves tedious computations; however, the modern digital microcomputer facilitates and speeds up such complicated and time-consuming computations. Moreover, in the majority of applications, its ability to store and access large amounts of information plays the dominant part and is considered to be its primary characteristic. The significance of the computer operation lies behind the good combination of hardware and software. For the purpose of our study a PC coupled with a STATGRAPHICS software was used.

In solving any problem, with or without a computer, it is necessary to define a set of data to represent the real situation. The choice of such data must be guided by the problem to be solved and by the tool that is to solve the problem. The choice of the way to represent the data is often a fairly difficult one and must, always, be made in light of the operations that are to be performed on the data.

Before running the analysis for the present research, the data were screened to determine whether data points needed correction or elimination. Projects that had many missing variables were rejected. In addition, projects which lie far from the mean were also eliminated.

An important point worth mentioning before reading the subsequent modeling sections. When an independent variable, X, fails to show an impact upon a dependent variable, Y, given that other independent variables are already in the regression model. This is not the same as saying that X is unrelated to Y. It simply says that the other independent variables have already explained a portion of Y and X cannot explain anything more about Y. It is possible that X is related to Y but is not needed once the other independent variables are in the model [**Albright, 1987**]. In such cases, data can be represented in a different format such as the O-U factor treatment discussed in section 2.3.3. Alternatively, as more observational data become available, the model's coefficients can be re-evaluated.

Finally, the cost models developed in this study do not account for costs which are not featured in the tender document but paid directly by the client such as design, supervision, land acquisition, and public utility.

4.2 PIPELINE COST MODEL

The output of this model will produce the estimated tender price of a pipeline project including the following items and corrected to January 1993:

A) GENERAL:

- General and Preliminaries
- Contingencies
- Associated civil works

- Profit of Contractor

B) MATERIALS:

- Pipes
- Fittings
- Valves
- Other necessary materials

C) INSTALLATION:

- Pipe laying
- Daywork
- Complementary Pipe laying works such as pressure testing, pipeline disinfecting, etc..

3.4.2.1 MODELING APPROACH:

Developing a regression model for a real problem is never a simple process. For a defined dependent variable, it is necessary to develop a long list of potential independent variables that have an impact on the dependent variable. Then a certain amount of creativity is essential in order to reduce the long list of independent variables to a shorter list by various means. The functional form of the regression model will gradually be decided upon in conjunction with the development of the short list and the parameters of the model will be estimated using the collected data.

Selecting the set of variables to be included in the analysis is not predetermined. In fact, it is the first and most crucial part of the analysis.

Initially all of the variables in Table 3.4 were entered in the model; the results of which are depicted by the computer output shown in figure 3.4.

The combined effect of those variables is considered satisfactory (Adjusted R^2=0.9635); however, many of those variables do not explain much about the model (Significance level > 0.05), so the first step was to remove those variables as their presence disturbs the other explanatory variables. The correlation matrix in Appendix C was calculated in order to detect the highly correlated variables (R > 0.6). When two variables were highly correlated, the one with the higher significance level was dropped. At the end of this variable-elimination-process, the following variables were eliminated:

1) Distance
2) Profile
3) Vicinity of site
4) Ground condition
5) Scheme type
6) Length of trenchless road crossing

TABLE 3.4 Initial List of Variables Considered in the Pipeline Model

VARIABLE	ABBREVIATION	UNITS	COMMENTS
1. Average diameter	DIA	mm	
2. Proportion of "DI" pipes length to total length	DI	Proportion	
3. Duration of project	DUR	Month	
4. Distance from contractor's base to project's site	DISTANCE	Km	
5. Description of the route's profile (Hilly, Moderate, or Flat)	FLAT, SEMI_HILLY	0 or 1	Dummy Variable
6. General Vicinity of site (No congestion, Mid congestion, or High congestion)	NO_CNGSTN MID_CNGSTN	0 or 1	Dummy Variable
7. Ground conditions, presence of rock	ROCK	m^3	
8. Scheme type (Transmission or Distribution Feeder)	TRANS	0 or 1	Dummy Variable
9. Length of Trenchless crossing or Thrust Boring	ROAD_XING	m	
10. Length of Wadi crossing	WADI_XING	m	

Model fitting results for: PIPE.RATE

Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	80.672293	47.266334	1.7068	0.1033
PIPE.DIA	0.25112	0.029787	8.4305	0.0000
PIPE.DI	8.373798	6.893502	1.2147	0.2386
PIPE.DUR	-0.893635	1.115907	-0.8008	0.4326
PIPE.DISTANCE	0.051347	0.023313	2.2025	0.0395
PIPE.FLAT	-20.328393	10.739128	-1.8929	0.0729
PIPE.SEMI_HILY	-26.227887	11.656644	-2.2500	0.0359
PIPE.NO_CNGSTN	-80.021221	39.534176	-2.0241	0.0565
PIPE.MID_CNGSTN	-85.463842	38.64839	-2.2113	0.0388
PIPE.ROCK	-0.000408	0.002164	-0.1884	0.8525
PIPE.TRANS	-15.92785	8.504449	-1.8729	0.0758
PIPE.ROAD_XING	0.010296	0.020629	0.4991	0.6232
PIPE.WADI_XING	0.004178	0.00717	0.5827	0.5666

R-SQ. (ADJ.) = 0.9635 SE= 13.189326 MAE= 7.543226 DurbWat= 1.749
Previously: 0.0000 0.000000 0.000000 0.000
33 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Figure 3.4 Pipeline Model Fitting Results Based on the Initial List of Variables

Leaving the following variables in the model:

1) Diameter
2) Proportion of DI pipes
3) Duration of the project
4) Wadi crossing

When this initial model was created, concern was voiced at the absence of those variables felt to be important., even though could not demonstrate a statistical importance. Nevertheless, practical experience indicates that scheme costs are radically affected by variations in factors of this sort. At that point a practical treatment was used by introducing an O-U factor adopted from the previously mentioned WRC study. The scores of the O-U factor were adopted, with minor modifications in some variables, from the WRC study and considered applicable because they measure relative rather than absolute levels and they were developed based upon the engineering characteristics of the projects. Table 3.5 exhibits the weights of those variables.

The sum of the 7 scores for a contract constitutes the O-U factor, and is an attempt to summarize how easy or difficult the project is, and hence whether it is likely to be cheaper or more expensive than the average.

In spite of the explanation power of the diameter factor (DIAMETER), it is believed from practical experience that the cost of a pipe is proportional to

TABLE 3.5 Weights of Variables Considered in the O-U Factor

CONTRIBUTORY FACTOR	RANGE	WEIGHTING	COMMENTS
1. Depth range (m)	As per the specifications	Score 1 point for every depth range featured in contract	Diversity of depths might indicate an increase in the complexity of the scheme, and necessitate a variety of excavation and pipe-handling techniques.
2. Diameter range (mm)	≤ 100 100 ≤ 200 200 ≤ 300 300 ≤ 600 600 ≤ 900 900 ≤ 1200	Score 1 point for every depth range featured in contract	Diversity of diameters might indicate an increase in the complexity of the scheme, and necessitate a variety of excavation and pipe-handling techniques.
3. General vicinity of site.	Easy/Rural Moderate/Suburban Difficult / Urban	1 3 8	The vicinity of the site will affect costs associated with : i) Site access; ii) Restrictions on site operations.
4. Ground conditions	Normal Soil Rock	1 8	The inclusion of the ground type is necessary as excavation cost is known to depend upon soil conditions.
5. Scheme type	Transmission main Distribution Feeder	1 3	Distribution projects are more difficult to handle due to branching
6. Construction method	Trenching Pipe jacking	1 7	Trenchless crossing (pipe jacking) needs a special thrust boring equipment and technique which in turn has a proportional impact upon the cost.
7. Distance (km)	≤ 40 ≤ 250 ≥ 250	1 3 8	Remote sites costs more than locals due to the added transportation costs.

its cross sectional area or the squared diameter. Moreover, a scatter gram of the diameter factor against the unit cost was investigated to confirm this belief. Hence, the DIAMETER factor was replaced with the squared diameter (DIA_SQR).

When the O-U factor and the DIA_SQR were introduced into the model, the computer output in figure 3.5 was generated.

Clearly, the Adjusted R^2 , Standard Error of Estimate (SE) , the Mean Absolute Error (MAE) ,the Durbin-Watson statistic have improved. In addition, the significance level of the individual explanatory variables have substantially improved by going below 0.05. Even though the significance level of the O_U factor is above 0.05, it is well below the significance level of its constituent variables when considered individually. Then it was decided to re evaluate the O_U factor by eliminating its significant variables which were determined to be the ground condition and the construction method. New values for the O_U were calculated and inserted into the model to produce the computer output shown in figure 3.6.

Clearly, the predictability of the model has increased (R^2=0.9906, whereas a value above 0.8 is considered satisfactory when modeling a real problem [Albright, 1987]. Moreover, all other statistics are kept within acceptable ranges.

Model fitting results for: PIPE.RATE

Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	21.333335	5.883099	3.6262	0.0012
PIPE.DIA_SQR	0.000244	0.00001	24.0847	0.0000
PIPE.DI	9.406574	3.27079	2.8759	0.0078
PIPE.DUR	-1.331667	0.4625	-2.8793	0.0077
PIPE.O_U	-0.10564	0.373148	-0.2831	0.7793
PIPE.WADI_XING	0.008538	0.002361	3.6168	0.0012

R-SQ. (ADJ.) = 0.9893 SE= 7.154548 MAE= 5.012954 DurbWat= 1.991
Previously: 0.9635 13.189326 7.543226 1.749
33 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Figure 3.5 Pipeline Model Fitting Results when O-U and DIA-SQR Factors were Introduced

Model fitting results for: PIPE.RATE

Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	11.553358	5.420003	2.1316	0.0423
PIPE.DIA_SQR	0.000256	0.000011	23.0037	0.0000
PIPE.DI	9.593977	2.907271	-3.3000	0.0027
PIPE.DUR	-1.322521	0.432032	-3.0612	0.0049
PIPE.O_U_MDFD	0.919127	0.458208	2.0059	0.0550
PIPE.WADI_XING	0.005603	0.00234	2.3940	0.0239

R-SQ. (ADJ.) = 0.9906 SE= 6.684376 MAE= 4.582459 DurbWat= 2.016
Previously: 0.9893 7.154548 5.012954 1.991
33 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Figure 3.6 Second Modification of the Pipeline Model

After Modifying O-U factor to O-U-MDFD

The analysis of variance (ANOVA) table, shown in figure 3.7, confirms the adequacy of the pipeline cost model by reporting a model significance well below 0.05. At that point it was decided to accept this model as a conceptual cost estimating tool for water pipeline projects in the Sultanate of Oman.

Finally, the cost model of a pipeline project is represented by the following mathematical equation:

UNIT RATE (RO/m) = 11.553358 + 0.000256*DIA_SQR + 9.593977*DI -1.322521*DUR + 0.005603*WADI_XING +0.919127*O_U

Where:

- DIA_SQR: Square of average diameter (mm)
- DI: Percent of Ductile Iron material in the pipeline system divided by 100
- DUR: Duration of the project (month)
- WADI_XING: Length of pipeline section requires wadi crossing protection (m).
- O_U: Over_Under factor; add up all corresponding scores for the factors in table 3.5 except Ground Condition and Construction Method

Analysis of Variance for the Full Regression

Source	Sum of Squares	DF	Mean Square	F-Ratio	P-value
Model	151511.	5	30302.3	678.193	.0000
Error	1206.38	27	44.6809		
Total (Corr.)	152718.	32			

R-squared = 0.992101
R-squared (Adj. for d.f.) = 0.990638

Stnd. error of est. = 6.68438
Durbin-Watson statistic = 2.01626

Figure 3.7 ANOVA Table for the Pipeline Cost Model

It worth mentioning here that failure of Ground Condition to show an impact upon the cost may be attributed to an inconsistent data and/or other variables are already explaining the variation of the Ground Condition.

3.4.3 RESERVOIR COST MODEL:

This model estimates the tender price of a reservoir including the costs of the following items corrected to January 1993:

A) GENERAL:

- General and Preliminaries
- Contingencies
- Daywork
- Profit of contractor

B) MATERIALS:

- Concrete
- Reinforcement Steel
- Shuttering
- Interlinking Pipes
- Other associated materials such as joint sealant, necessary coatings, etc.

C) CONSTRUCTION:

- General Civil Work Construction
- Associated Pipework Installation
- Complementary construction such as concrete chambers

3.4.3.1 MODELING APPROACH:

All potential variables listed in table 3.6 were inserted into the model; however, the results were not satisfactory as shown by the computer output in figure 3.8.

The most annoying result was the low value for the Adjusted R^2. Also, it was observed that significance levels of all explanatory variables were very high, thus, requesting a major alteration which could have a global impact upon the model. The first step in this direction was to replace the dependent variable, the "Unit Rate" (RO/m³), with the "Total Cost" to produce the computer output in figure 3.9.

TABLE 3.6 Initial List of Variables Considered in the Reservoir Model

VARIABLE	ABBREVIATION	COMMENTS
1. Storage capacity (m3)	CAPACITY	
2. Duration of project (month)	DUR	
3. Distance from contractor's base to project's site (km)	DISTANCE	
4. Ground conditions, presence of rock (m3)	ROCK	
5. General Vicinity of site	SITE	measured with the WRC weightings

Model fitting results for: RSRVR.RATE

Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	94.04512	92.799344	1.0134	0.3500
RSRVR.CAPACITY	0.000709	0.00149	0.4762	0.6508
RSRVR.DURATION	-7.7074	12.136672	-0.6351	0.5488
RSRVR.DISTANCE	0.153645	0.125257	1.2266	0.2659
RSRVR.ROCK	0.008229	0.012769	0.6444	0.5431
RSRVR.SITE	-6.298865	19.329148	-0.3259	0.7556

R-SQ. (ADJ.) = 0.2229 SE= 46.773147 MAE= 22.026542 DurbWat= 2.428
Previously: 0.0000 0.000000 0.000000 0.000
12 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Figure 3.8 Reservoir Cost Model Based on Initial List of Variables

Model fitting results for: RSRVR.COST

Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	-1.698613E5	2.101472E5	-0.8083	0.4498
RSRVR.CAPACITY	32.673245	3.373511	9.6852	0.0001
RSRVR.DURATION	39585.346935	2.748389E4	1.4403	0.1998
RSRVR.DISTANCE	151.189186	283.649198	0.5330	0.6132
RSRVR.ROCK	4.093385	28.916748	0.1416	0.8921
RSRVR.SITE	310.193482	4.377149E4	0.0071	0.9946

R-SQ. (ADJ.) = 0.9792 SE= 105919.324605 MAE= 54402.397484 DurbWat= 1.277
Previously: 0.2229 46.773147 22.026542 2.428
12 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Figure 3.9 Reservoir Cost model Fitting with 'Total Cost' Being the Dependent Variable

Clearly, a substantial improvement has occurred in the predictability of the model by the significant increase in the value of the Adjusted R^2. Also, the significance of most variables improved but did not drop below the acceptable limit. Next, significant and highly correlative variables were removed after inspecting the correlation matrix in Appendix C.

Site and duration variables were removed, leaving the model with the capacity, distance, and Rock variables only. The computer output in figure 3.10 shows the estimated coefficients and the corresponding statistics of the model. Figure 3.10 shows that all statistical measures have become a bit worse except the D-W statistic which improved slightly (approached the value of 2). Moreover, the distance variable worsen, whereas the significance level of the site variable has moderately improved. Indeed, this result was not satisfactory and an O-U factor was built to explain the variations which could not have been represented yet.

Table 3.7 shows the factors underlying the O-U variable which was considered in the Reservoir Cost Model. Figure 3.11 shows the computer output of the reservoir model fitting results including the effect of the O-U variable. All the statistics of the model have improved. However, the significance of the O-U factor shows a significant deviation from the acceptable limit of 0.05, and in spite of slight improvement in the significance of the duration variable it is not satisfactory. During the diagnosis of the pipeline's O-U factor ,considerable improvement was realized when the ground

Model fitting results for: RSRVR.COST

Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	1.068103E5	7.550083E4	1.4147	0.1949
RSRVR.CAPACITY	36.488198	2.038191	17.9022	0.0000
RSRVR.DISTANCE	-95.289836	218.403595	-0.4363	0.6742
RSRVR.ROCK	5.156037	11.96743	0.4308	0.6780

R-SQ. (ADJ.) = 0.9789 SE= 106496.600711 MAE= 66142.085697 DurbWat= 1.506
Previously: 0.9792 105919.324605 54402.397484 1.277
12 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

3.10 Reservoir Model Fitting Results After Removing the Correlative Variables

TABLE 3.7 Factors Underlying the O-U Variable in the Reservoir Cost Model

CONTRIBUTORY FACTOR	RANGE	WEIGHTING	COMMENTS
1. General vicinity of site.	Easy/Rural Moderate/Suburban Difficult / Urban	1 3 8	The vicinity of the site will affect costs associated with : i) Site access; ii) Restrictions on site operations.
2. Ground conditions	Normal soil Rock	1 8	The inclusion of the ground type is necessary as excavation cost is known to depend upon soil conditions.
3. Distance (km)	≤ 40 ≤ 250 ≥ 250	1 3 8	Remote sites costs more than locals due to the added transportation costs.

Model fitting results for: RSRVR.COST

Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	-1.228453E5	1.220636E5	-1.0064	0.3437
RSRVR.CAPACITY	33.249498	2.797923	11.8836	0.0000
RSRVR.DURATION	31922.486622	1.778533E4	1.7949	0.1104
RSRVR.O_U	4173.591122	6756.638383	0.6177	0.5539

R-SQ. (ADJ.) = 0.9842 SE= 92115.425871 MAE= 55511.366313 DurbWat= 1.371
Previously: 0.9789 106496.600711 66142.085697 1.506
12 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Figure 3.11 Reservoir Model Fitting Results Including the O-U Factor condition variable was excluded. A similar treatment was carried out in the Reservoir's O-U factor. Moreover, as a diagnostic measure, the scatter gram of the duration variable was inspected and found to best fit a "growth curve" of the factor e^x as suggested by Albright, 1987.

Finally, the parameters of the reservoir cost model were estimated using the following variables:

- CAPACITY: the storage capacity of the reservoir (m^3)
- e^x: where x being the duration of the project (month)
- O-U: the Over-Under factor including the General Vicinity of site and distance to the project's location.

The computer output in figure 3.12 explains the new model. The outlined variables were able to significantly represent the variation of the model and were able to explain much about it as reported by the very high Adjusted R^2. Moreover, all the variables have dramatically improved by reporting a significance level well below 0.05. In addition, all other remaining statistics are within the acceptable limits. As a final measure to check the adequacy of the model, the ANOVA table shown in figure 3.13 was generated by the computer.

Obviously, the p-value of the F-statistic is well below the 0.05

Model fitting results for: RSRVR.COST

Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	-2.107362E5	7.553959E4	-2.7897	0.0236
RSRVR.CAPACITY	64.802231	5.529629	11.7191	0.0000
RSRVR.DUR_MDFD	-8.094229	1.589404	-5.0926	0.0009
RSRVR.O_U_MDFD	28218.006379	8147.229819	3.4635	0.0085

R-SQ. (ADJ.) = 0.9946 SE= 53763.808263 MAE= 33656.258615 DurbWat= 1.604
Previously: 0.9842 92115.425871 55511.366313 1.371
12 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Figure 3.12 Reservoir Model Fitting Results Including the Duration as e^X and Excluding Ground Condition From the O-U Factor

Analysis of Variance for the Full Regression

Source	Sum of Squares	DF	Mean Square	F-Ratio	P-value
Model	5898323669717.	3	1966107889906.	680.185	.0000
Error	23124376631.	8	2890547079.		
Total (Corr.)	5921448046349.	11			

R-squared = 0.996095 Stnd. error of est. = 53763.8
R-squared (Adj. for d.f.) = 0.99463 Durbin-Watson statistic = 1.60383

Figure 3.13 ANOVA Table for the Reservoir Cost Model significance level, indicating an adequate model. Finally, this model was considered satisfactory to provide a conceptual estimate for the capital cost of Water Storage Reservoirs in the Sultanate of Oman.

Finally, the reservoir cost model is represented by the following mathematical equation:

$$\text{COST (RO)} = -2.107\text{X}10^{5} + 64.8022*\text{CAPACITY}$$
$$-8.09423*e^{\text{DURATION}} + 28218*\text{O\_U}$$

Where;

- CAPACITY: Storage capacity of the reservoir (m^3)
- DURATION: Duration of the project (month)
- O-U: Over-Under factor including the General Vicinity of Site and Distance to the project's location only.

3.4.4 PUMPING STATION COST MODEL:

The output of this model includes the estimated cost of the following items corrected to January 1993:

A) GENERAL:

- General and preliminaries
- Contingencies
- Associated civil works
- Profit of contractor

B) MATERIALS:

- Pumps
- Motors
- Suction head
- Delivery head
- Crane
- Wiring and electrical items
- Pump House
- Other complimentary materials such as sump pump, doors, windows, etc.

C) INSTALLATION:

- Construction of pump house
- Pump and motor installation
- Associated mechanical & electrical installations

3.4.4.1 MODELING APPROACH:

When the unit rate (RO m^3/Hr) was used as a dependent variable, the created model produced serious unsatisfactory statistical results such as low Adjusted-R^2, very large Mean Absolute Error (MAE), out of order Durbin-Watson statistic and large level of significance for the various variables. Therefore, the only promising solution was to use the total cost of the pumping station as the dependent variable. Nevertheless the coming paragraphs explains the characteristics of the model development procedure.

Statisticians recommend keeping the number of explanatory variables well below the number of available observations. However, it is an acceptable practice to start with all potential variables and eliminate throughout the model creation procedure. Initially all of the following potential variables were considered:

1) Normal pumping capacity
2) Normal pumping head
3) Number of installed pumps
4) Type of pump station (Forward/Booster)
5) Capacity of installed crane
6) Duration of the project
7) Over-Under factor; being a function of general vicinity of site and distance

to project.

As a result, the computer responded with an error message saying "Not Enough Observations to Fit Model.". This message indicates that the explanatory variables are too many compared to the available number of observations. Hence, one or more variables need to be eliminated. Since the computer did not return any statistical measures about the model; then, the elimination process must be based upon the common engineering sense and general knowledge of the study in hand.

From previous development procedures, it was shown that the O-U variable was a factor attempting to assess the difficulty of the project. Also, the explanation power of the O-U factor showed minor influence upon the dependent variables compared to the other influential variables. That was stated by the minor improvement in the Adjusted R^2 value when the O-U factor was introduced into the model. Therefore, the first variable to be eliminated was the O-U factor; and again, the computer returned the same message: "Not Enough Observations to Fit Model." Next, the variable elimination procedure continued and finally it was found that no more than five variables were allowed in the model. Different combinations of variables were tested, however, the following variables produced a perfect fit:

1) Normal pumping capacity
2) Normal pumping head

3) Type of pump station (Forward/Booster)

4) Capacity of installed crane

5) Duration of project

Figure 3.14 portrays the computer output reporting the characteristics of the model. This perfect fit indicates that all the observed points lie on the model line. This is not strange because there are only six observations used to build the model. Thus, the reliability of this model can be improved if more observations are appended to the data sample.

Hence, with the available observations, that model was considered satisfactory to estimate the cost of water pumping station projects in Oman.

The following mathematical equation is representing the cost model of the pumping station:

$$\begin{aligned}\mathbf{COST(RO)} = {} & \mathbf{45521.97 + 451.79{*}CAPACITY - 3142.48{*}HEAD -} \\ & \mathbf{1.042X10^{5}{*}DURATION + 1.312X10^{5}{*}TYPE} \\ & \mathbf{+\ 2.628X10^{5}{*}CRANE}\end{aligned}$$

```
                  Model fitting results for: PUMP.COST
--------------------------------------------------------------------------
Independent variable          coefficient  std. error   t-value  sig.level
--------------------------------------------------------------------------
CONSTANT                     45521.975646
PUMP.NRML_CPCTY                451.795927
PUMP.NRML_HEAD               -3142.479568
PUMP.DURATION                 -1.041658E5
PUMP.FRWRD_TYPE                1.311572E5
PUMP.CRANE_CPCT                2.628063E5
--------------------------------------------------------------------------
R-SQ. (ADJ.) = 1.0000  SE=       0.000000  MAE=       0.000000  DurbWat=  2.122
Previously:    0.0000            0.000000             0.000000            0.000
6 observations fitted, forecast(s) computed for 0 missing val. of dep. var.
```

Figure 3.14 Pumping Station Model Fitting Results Indicating a Perfect Fit

Where;

- CAPACITY: Pumping capacity of the station (m^3/Hr)
- HEAD: Normal operating pressure head (m)
- DURATION: Duration of project (month)
- TYPE: Type of pumping station (Forward=1 Booster=0)
- RANE: Loading capacity of crane (ton)

CHAPTER 4

CCES: A COMPUTERIZED COST ESTIMATING SYSTEM

4.1 INTRODUCTION

The computer-aided cost estimating market was broadened in the last few years with the addition of estimating programs for the microcomputer. In the early 1980's, virtually all cost estimating programs ran on time sharing or mini computer systems. However, the capabilities of personal computers have grown dramatically and their prices have dropped significantly. Microcomputer-based estimating programs have the necessary capabilities to perform detailed estimates, as well [Akeel, 1989].

This part of the thesis integrates all the preceding stages into a single ,usable tool. This was accomplished by developing a computer program capable of receiving the data, executing the previously cost models, and finally presenting the results. This computerized system was called CCES

(Computerized Cost Estimating System) and was developed via the BASIC language because of the following reasons:

- ease of use
- sufficient power
- the arithmetic computations required by CCES is not demanding and hence does not require more powered-computer language such as FORTRAN or PASCAL.

4.2 STRUCTURE OF CCES

CCES is a menu-driven and a user-friendly application software constitute of the following components:

1) Main Program:

The main program is the smallest portion of CCES (line 10 to line 320). It contains the following rule sets:

A) Start-Up and introduction:

These rule-sets start the system, clear all variables, and introduce the thesis.

B) Displaying Main Menu:

The main menu for CCES is displayed, and the user is given the available options to select from.

2) Cost Estimating Subroutines of Water Supply Projects:

Subroutines are constituted of three parts, namely, PIPELINE (line 330 to line 3490), RESERVOIR (line 3500 to line 6160), and PUMPING STATION (line 6170 to line 8290), these three parts basically handle the following operations:

A) Displaying a Sub-Menu:

The user is given the choice of navigating within the selected water supply project subroutine.

B) Data Input, Storage, and Retrieval:

The user is asked to input the data required by the system and then given the option to save the input in a permanent data file. Moreover, the user is given the choice to prescribe the name of the data file. CCES automatically assigns extensions PIP, RSR, and PMP to the data files of pipeline, reservoir, and pumping station projects respectively. The data in those files can be retrieved by the system when required and used as an input data.

C) Model Execution:

Based on the data supplied by the user or data retrieved from an old file, the corresponding cost model is executed.

D) Output Presentation:

The resulting output the executed cost model is presented on the screen in tabulated format. The estimated tender price is presented with different annual price escalation rates, giving the user the advantage of inspecting the effect of the different rates on a single screen. All results are reported with their statistical significance (i.e. the corresponding Mean Absolute Error (MAE) of the model).

E) Printing Output:

The user is given the option of producing a hard copy portraying all input values and the resulting output with full explanation and comments.

Flow Chart of CCES is shown in Figure 4.1 and the program is listed in Appendix E.

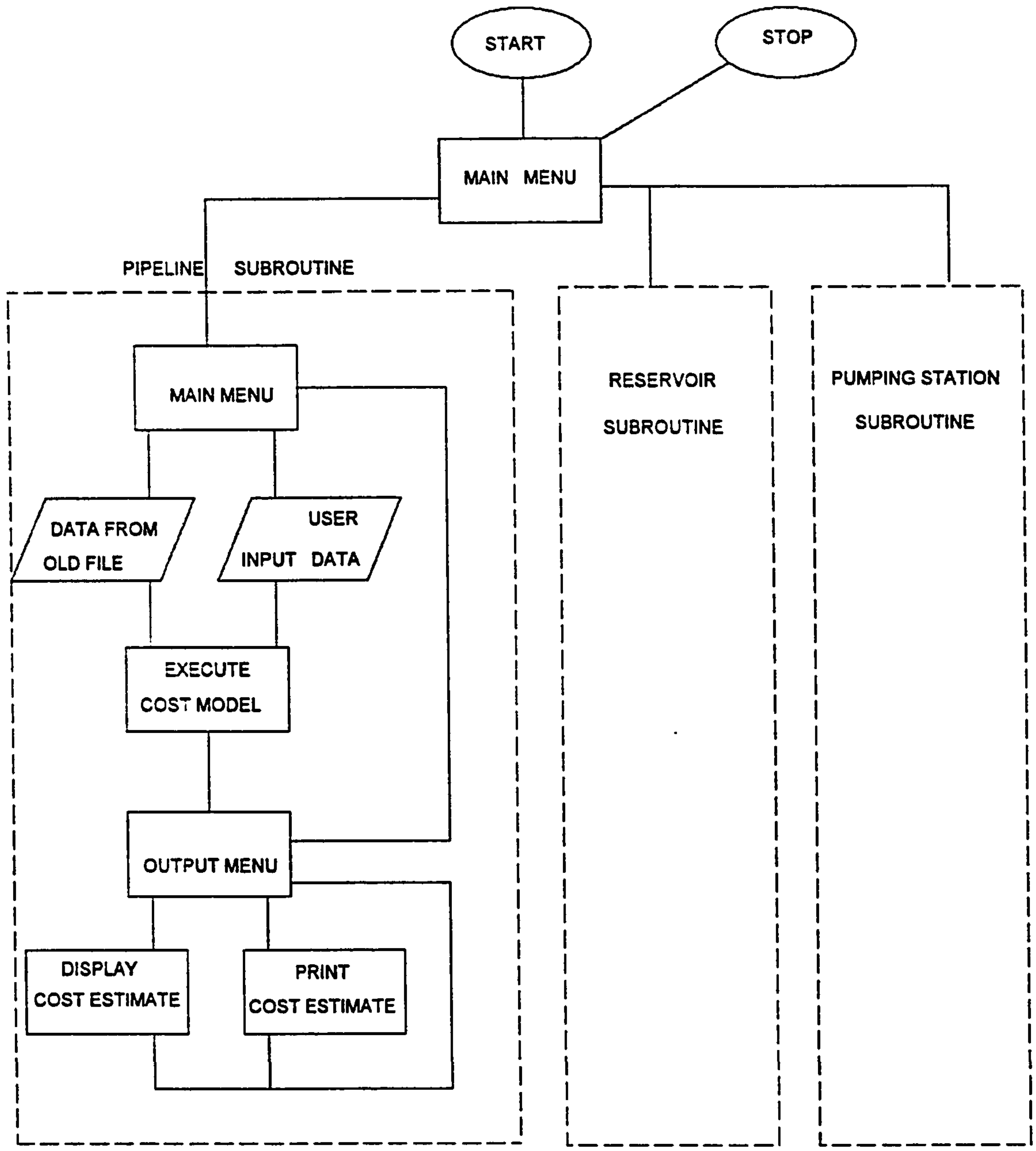

Figure 4.1 Flow Chart of CCES

4.3 COST ESCALATION

The underlying cost estimating models of the three project types under consideration were based on the available data prices of tenders collected throughout the period from 1979 to 1992 and corrected to the base date of January 1993. In other words, the results generated by the models are the estimated construction costs as if they were tendered in January 1993. Since all cost estimates will be beyond this base date, the researcher has provided a possible range of escalation rates for each model. CCES was designed to escalate the estimated costs accordingly based on the following formula:

$$\text{Estimated Cost}_{(\text{Future})} = \text{Estimated Cost}_{(\text{January/1993})} * [\, 1 + i/100 \,]^{n}$$

where, i: annual escalation rate of prices (%) since January 1993 to the specified future date.

n: time difference between January 1993 and future date; calculated as follows:

$$n = [\text{Future Year} - 1993] + [(\text{Future Month} - 1) / 12]$$

4.4 UPDATING CCES

The coefficients of the models were determined by the regression analysis via a software package called STATGRAPHICS. This software can store in data files "Observational Data" upon which the models were built. Those data files were called PIPE, RSRVR, and PUMP to store the data of Pipeline, Reservoir, and Pumping Station respectively and were saved in ASCII format to facilitate retrieval by most commercial statistical packages. Clearly, if existing data is altered or more observational data is appended to those data files, and subsequent regression analysis is carried out; the models' coefficients will be changed accordingly. Hence, when more tender prices (observations) become available in the future, they can be appended to the existing data files and the models' coefficients can be re-determined by any statistical package. Finally, the fresh coefficients calculated by the statistical analysis can easily be entered into the cost models within CCES to take into consideration the effect of the newly appended cases. The updating process of CCES should be carried out by trained engineers only.

However, considerable difference in the models' coefficients can not occur upon appending one or two observations; thus, the updating of the models should not be carried out unless a sufficient number (five or more) of observations become available. From the researcher's experience with MEW's Water Projects Department, this number of observations (tender prices of projects) could only become available within about 3 years for pipeline projects and 5 to 6 for reservoir and pumping station projects. Therefore, the updating of the cost models is not necessary, on average, within less than five-year interval.

4.5 REQUIREMENTS OF CCES

The required hardware to execute the CCES is as follows:

- IBM computer or compatible
- Color monitor and a color/graphics adapter
- Minimum of one diskette drive
- Minimum of 512 kilobytes of RAM memory
- Printer is optional

4.6 PROCEDURE FOR USING CCES

The following steps describe the basic procedure for using CCES:

1) Insert the floppy disk containing the CCES in drive A or B.

2) Type in the diskette drive letter followed by a colon such as A: or B:, followed by a carriage return.

3) Call up the GWBASIC program by typing GWBASIC followed by a carriage return.

4) Type in LOAD"CCES" followed by a carriage return.

5) Type in RUN followed by a carriage return.

6) The introduction screen will appear, the user may then read and press carriage return to display the main menu.

7) The user can select one of the options displayed including the EXIT from the program.

Details of an application example of estimating a pipeline project can be found in Appendix D.

CHAPTER 5

VALIDATION OF CCES

Just as the effectiveness of the various instruments and drugs used by physicians must be validated, so the accuracy, utility, and dependability of consultation programs must eventually be assessed. Any computer software should perform its required task, be free of any technical errors, and reach right conclusions.

The objective of conducting testing is to attain confidence in the CCES. The performance of CCES as a conceptual cost estimate, however, has been continuously tested, at the early stages, when developing the cost estimating relationship. Statistical testing has been conducted to achieve the best cost estimating models based on the available data as explained in chapter 3. Also, program debugging was seriously carried out during the development of the CCES until an error-free program was attained.

The prediction accuracy of a regression model depends heavily upon the accuracy of the data it has been based on. This means that CCES will eventually improve its estimating accuracy when new and accurate information is appended to its data files. However, in order to test the accuracy of the estimating models within CCES, the cost of each project included in the analysis has been estimated using CCES and compared with its actual cost. Table 5.1 shows the results of the tests.

For a conceptual estimating purpose, those results are acceptable and comply very well with the standards of AACE which requires that any order of magnitude estimate should not exceed ± 30% of the actual cost [**Manzanera, 1991**]. However, the validation of CCES should be re-evaluated based on costs of projects other than those used to determine the models.

TABLE 5.1 Results of Testing the Adequacy of the Model

PROJECT TYPE	ABSOLUTE AVERAGE ERROR (%)	ABSOLUTE AVERAGE WEIGHTED ERROR (%)	COMMENTS
Pipeline	13	8.6	90% of the projects were estimated within 25% of their actual costs
Reservoir	14	7.4	92% of the projects were estimated within 27% of their actual costs
Pumping Station	0	0	All observational points fell on the model line due to the small sample size.

CHAPTER SIX

SUMMARY CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

6.1.1 SUMMARY OF THE STUDY:

Chapter One states that Conceptual estimating is one of the most essential business skills in the construction industry. Conceptual estimates are made before construction drawings are completed, often before they are hardly begun. They are used to make feasibility studies, to set a construction budget, and to control construction costs at the most critical stage, during the design.

Although computers have not been fully utilized in the construction industry, they have a great potential to enhance cost estimating and construction management practices.

Quantities of water resources in the Arabian Gulf countries are extremely limited. Thus, proper planning and management is very important to meet the increasing demand for water caused by the accelerating industrial development in the region.

Although this research especially focused on Oman, its profile is relevant to the water and construction industry particularly in the Gulf Countries.

The Directorate General of Water (DGW) at the Ministry of Electricity and Water (MEW) in Oman has undertaken sizable Domestic Water Supply projects; however, the history and statistics of these completed projects has not been captured in the appropriate manner so that it may be utilized to help in decision-making on future projects. Moreover, no approved methods are being used to produce cost estimates in the DGW. As a solution, a Computerized Cost Estimating System (CCES) was proposed to estimate the costs of Domestic Water Supply Projects within an acceptable range of accuracy. CCES should be capable of producing such an estimate when the available information is no more than a conception in the mind of the owner. Finally, this research work was limited to three types of domestic water supply projects, namely Pipelines, Reservoirs, and Pumping Stations.

Chapter Two thoroughly presents the literature relevant to the research subject, explored different types of construction cost estimates, and outlined its future outlook. The American Association of Cost Engineers (AACE) classified the various capital cost estimates as in Table 6.1.

Among the various cost estimating methods discussed in chapter two; a statistically-based cost estimating models which was investigated and referred to as Multiple-Parameter CER Models. This cost estimating technique utilizes the physical and/or performance characteristics of the project to estimate its construction cost. Moreover, Multiple Parameter CER Models require tedious mathematical manipulation and instantaneous access to historical cost databases. The difficulties arising from such complex operations can be overcome by the use of powerful computers.

Finally, repeatedly used statistical definitions were presented to facilitate the reading and understanding of this manuscript.

Chapter Three illustrates the steps undertaken to develop the cost models of the domestic water supply under consideration.

Initially, researcher presented the thesis subject for key persons in the DGW to call their attention toward the research and consequently attain cooperation in the subsequent stages. Also, DGW's main consultants and contractors were informed and subsequent discussions were carried out with them.

Table 6.1 AACE classification for different types of estimates

Type of Estimate	Purpose	Accuracy
Order of Magnitude	Used by owner for planning and budgeting	-30% to + 30%
Preliminary	Used by A/E to evaluate possible design alternatives and to evaluate contractor bid	-15% to +30%
Definitive	Used by contractor to bid for the project	-5% to +15%

Next, the cost determinant factors were identified via an extensive review of tender documents and international literature, consultation with the DGW Project Engineering Department, and discussions with consultants and contractors. Those factors were classified into common cost factors, pipeline cost factors, reservoir cost factors, and pumping station cost factors. The common factors are those influencing the cost of all project types whereas the other factors basically described the performance and characteristics of each project type mentioned, hence, influencing its own cost.

Originally, the cost models were to be based upon the final account costs. However, tender figures were used, instead, for the following reasons:

1) Unavailability of final account cost.
2) Tender figure are within ±5% of the final account cost.
3) Difficulties associated with inflation adjustment for final account costs.

Nevertheless, data was not readily available within the DGW archive and researcher had to approach the MMI consulting firm which supplied the majority of data. Unfortunately, the available quantity of data was limited specially for the pumping station projects. This collected data was adjusted for escalation effect to the base date of January 1993.

Based on the outcome of the above stages, cost models were developed using a 486-PC coupled with STATGRAPHICS statistical package to handle the extensive regression analysis.

Chapter Four integrates all the predecessor stages into a single and usable tool. That was accomplished by developing a computer program capable of receiving data, executing the cost models, and finally presenting and printing the results. This computerized system was referred to as CCES (Computerized Cost Estimating System) and was developed via the BASIC computer code. CCES is a user-friendly software application and novice users can quickly become acquainted with.

Chapter Five demonstrates the validity and accuracy of the cost models and shows their compliance with the AACE standards. The Absolute Average Errors (AAE) of pipeline, reservoir, and pumping station cost models were 13%, 14%, and 0% respectively. Also, their Absolute Average Weighted Errors (AAWE) were 8.6%, 7.4%, and 0% respectively.

The characteristics of pipeline and reservoir cost models were very satisfactory: reporting an R^2 above 0.99 and at the same time producing a significance level for all variables below 0.05. On the other hand, the pumping station cost model reported a perfect fit, indicating that all observed points lie on the model line. That was not an astonishing result since only six observations were used to create the model, however, as more observations become available; more realistic results can be obtained.

6.1.2 SUMMARY OF THE RESULTS:

The following points summarize the major findings and results produced by this study:

1) Costs of the domestic water supply projects have been successfully represented by the cost models developed by the regression analysis of historical cost data.

2) Considerable quantity of cost data is being generated in the DGW. However, this cost data has not been archived in the appropriate manner so that it may be utilized to help in decision-making on future projects.

3) Conceptual cost estimating at the DGW is not only constrained by the lack of a location index or an escalation factor, but also by being limited to a few senior engineers using subjective decisions rather than methods created by research and validated by experience.

4) The cost determinant factors, discussed earlier, exert different impacts upon their cost model. However, the diameter of a pipeline, storage capacity of a reservoir, and the pumping capacity of a pumping station are dominant factors influencing their corresponding cost models.

5) Since the accuracy of any regression model depends considerably on the set of independent variables that are used to predict the dependent variable, a new variable, which was called Over-Under (O-U) factor, has been introduced into the analysis in order to assess the likelihood of a project to be difficult or easy. The O-U factor was introduced after the failure of its underlying factors to show significance upon the predictability of the models when considered individually. The introduction of this independent variable has proven to be of significant aid in improving the prediction accuracy of the pipeline and reservoir cost models.

6) This thesis demonstrated that a well thought-out integration among the science of cost estimation, statistical analysis, and computer technology can, effectively, enhance practices of cost estimating.

6.2 RECOMMENDATIONS

6.2.1 GENERAL RECOMMENDATIONS:

Based on the outcome of this thesis, the following general recommendations can be made:

1) Although CCES has been developed for the DGW's use in Oman, its techniques and principles remain relevant to the development of a conceptual estimating system in any domain, particularly in the Arabian Gulf countries such as Kingdom of Saudi Arabia. Hence, Water Industry practitioners in neighboring countries are advised to follow the profile set forth in this study to tailor their cost estimating systems.

2) The Directorate General of Water (DGW) in Oman is advised to use CCES as a reliable tool to estimate the construction cost of the domestic water supply projects considered in this study.

3) Collection of cost data in the DGW should be practiced as an integrated routine task within the current project management systems. The data collection forms in Appendix B can be used to gather cost data. Moreover,

DGW is advised to store the collected data in a computerized database to facilitate retrieval and statistical analysis.

4) DGW is advised to build its own cost indices for the various projects, work items, and the frequently used materials.

6.2.2 RECOMMENDATIONS FOR FURTHER STUDIES:

Since the refinement process of almost any research work is somewhat endless, the following recommendations provide niches for further studies:

1) When frequent model-updating becomes necessary, CCES can be linked with any appropriate statistical package supported with a data base management system to facilitate self updating of cost models.

2) It is quite likely that, with a larger sample of data, additional explanatory variables will become significant and some of the existing explanatory variables will become insignificant. Thus, Intelligent selection rules can be linked to CCES for selecting the set of variables to be included in the regression models. This way, CCES will have the power to eventually discard any independent variable currently in the models if it becomes insignificant in the future, and select another independent variable, such as the presence of rock, if it proves to be more significant.

3) Another important issue which could improve the estimating accuracy of the system is to develop a component estimate. The component level breaks down the project's cost into its parts, such as excavation, pipe laying, and concrete work, in case of a pipeline project. This can be accomplished if the cost of each project component can be obtained for all projects in the historical data. This will allow the development of several cost estimating relationships, one for each component, and the total estimated cost of a project will be the sum of the estimated cost of each component.

4) Throughout the development session of the cost models , several cost factors exhibited varying impacts upon the costs of the water projects under consideration. Thus, a value engineering program could be carried out in order to investigate those factors with the objective of exploring other alternatives.

5) An optimization procedure, life cycle costing, and a Geographical Information System (GIS) should be integrated with CCES to form a complete costing solution for the projects under considerations.

6) For a particular project type such as a pipeline, multiple models can be developed. Each model would account for a specific condition applicable to that project. For instance, a separate pipeline cost model can be developed for those pipelines laid in "rocky" areas only and another cost model for those laid in "soft soils."

7) Since uncertainty is an inherent feature of any cost estimate, a technique to address such uncertainty can be developed within CCES. The Range Estimating technique is a viable candidate.

8) It is recommended to expand the scope of the pipeline cost model to include distribution pipework to the level of consumer connection.

APPENDICES

APPENDIX - A

DATA USED FOR ANALYSIS

PIPELINE DATA

File PIPE 6/23/93 Page 1-1

row	OBSRVN	RATE	DIA	DI	DUR	DIA_SQR	DISTANCE	O_U	O_U_MDFD
1	1	19.38	100	1.	6	1.E0004	210	7	8.5
2	2	32.72	219	1.	2	5.E0004	0	16	9.5
3	3	119.87	595	1.	10	4.E0005	0	15	9.0
4	4	16.89	193	0.	6	4.E0004	230	15	9.0
5	5	11.85	145	0.	9	2.E0004	0	8	7.0
6	6	12.60	137	0.	9	2.E0004	0	10	6.5
7	7	11.57	141	0.	12	2.E0004	0	10	7.0
8	8	62.45	398	1.	6	2.E0005	0	16	6.0
9	90	20.07	225	0.	12	5.E0004	0	12	7.5
10	10	118.09	600	1.	2	4.E0005	0	7	4.5
11	11	123.93	600	1.	9	4.E0005	0	13	6.0
12	12	119.75	600	1.	6	4.E0005	0	9	5.0
13	13	17.35	100	1.	3	1.E0004	210	5	6.5
14	14	60.74	388	1.	2	2.E0005	0	12	4.5
15	15	34.55	155	1.	9	2.E0004	320	17	14.5
16	16	25.23	155	0.	9	2.E0004	320	17	14.5
17	17	49.67	277	0.	3	8.E0004	320	12	12.5
18	18	55.40	277	1.	3	8.E0004	320	13	12.5
19	19	38.23	295	1.	10	9.E0004	140	8	7.5
20	20	60.41	398	1.	4	2.E0005	0	8	5.0
21	21	18.60	156	0.	6	2.E0004	0	21	9.0
22	22	35.51	300	0.	4	9.E0004	0	15	8.0
23	23	15.45	136	0.	7	2.E0004	350	12	14.5
24	24	24.70	214	0.	6	5.E0004	0	13	8.0
25	25	20.26	126	0.	6	2.E0004	0	17	9.5
26	26	24.89	150	0.	3	2.E0004	230	7	7.5
27	27	30.19	98	1.	2	1.E0004	500	7	12.0
28	28	43.84	100	1.	2	1.E0004	500	9	13.5
29	29	20.79	118	0.	4	1.E0004	0	16	8.5
30	30	75.00	450	1.	6	2.E0005	320	15	11.5
31	31	12.85	142	0.	10	2.E0004	320	18	15.0
32	32	313.64	1000	1.	12	1.E0006	0	25	12.5
33	33	268.24	1000	1.	12	1.E0006	0	21	7.0

cont. PIPELINE DATA

File PIPE 6/23/93 Page 1-2

row	COST	LENGTH	FLAT	SEMI_HILY	NO_CNGSTN	MID_CNGSTN	ROCK	TRANS
1	6.01824E0004	3105.	0	1	1	0	0	0
2	1.70474E0005	5210.	0	1	0	1	50	0
3	1.59602E0006	13315.	0	0	0	1	7050	1
4	5.34702E0005	31660.	1	0	1	0	5700	0
5	2.89588E0005	24440.	1	0	1	0	100	0
6	3.05232E0005	24230.	1	0	1	0	100	0
7	5.63083E0005	48670.	1	0	1	0	200	0
8	5.94211E0005	9515.	0	1	1	0	3000	1
9	1.71139E0006	85260.	1	0	1	0	100	0
10	6.02246E0005	5100.	1	0	1	0	40	1
11	1.38001E0006	11135.	0	0	0	1	5500	1
12	1.59203E0006	13295.	0	1	1	0	5500	1
13	2.48137E0004	1430.	1	0	1	0	0	1
14	1.70078E0004	280.	1	0	1	0	144	1
15	1.82037E0006	52690.	0	1	1	0	4800	0
16	1.32935E0006	52690.	0	1	1	0	4800	0
17	4.02100E0005	8095.	1	0	1	0	500	1
18	4.48728E0005	8095.	1	0	1	0	500	1
19	1.69299E0006	44285.	1	0	1	0	1750	1
20	4.56362E0005	7555.	0	1	1	0	10	1
21	4.01319E0005	21580.	1	0	0	1	5000	0
22	1.45580E0005	4100.	0	1	1	0	1900	0
23	5.38844E0005	34885.	0	1	1	0	30	0
24	2.83006E0005	11460.	1	0	0	1	0	0
25	2.18396E0005	10780.	0	0	0	1	1700	0
26	2.66238E0005	10697.	1	0	1	0	60	1
27	7.69892E0004	2550.	1	0	1	0	150	1
28	5.78668E0004	1320.	1	0	1	0	45	0
29	8.71029E0004	4190.	1	0	0	1	750	0
30	6.78765E0005	9050.	1	0	0	1	5000	1
31	6.36739E0005	49570.	0	1	0	1	6000	0
32	5.65485E0006	18030.	0	1	0	0	7250	1
33	6.10605E0006	22763.	0	0	0	1	11350	1

cont. PIPELINE DATA

File PIPE 6/23/93 Page 1-3

row	ROAD_XING	WADI_XING	DEVIATION
1	0	0	45
2	40	220	24
3	200	885	7
4	270	750	52
5	0	0	3
6	0	400	0
7	0	400	18
8	54	550	0
9	0	175	17
10	0	20	2
11	100	1770	5
12	0	160	7
13	0	0	48
14	54	90	1
15	0	860	3
16	0	860	5
17	0	500	16
18	0	500	8
19	100	0	3
20	0	50	1
21	936	20	2
22	64	75	6
23	0	300	42
24	0	140	1
25	295	395	10
26	0	0	18
27	0	0	6
28	0	0	23
29	0	600	14
30	20	2000	16
31	120	100	48
32	485	5820	3
33	385	2860	6

RESERVOIR DATA

File RSRVR 6/23/93 Page 1-1

row	OBS	RATE	CAPACITY	DURATION	DISTANCE	ROCK	SITE	COST	O_U
1	****	53.186	18000.	9.0	0	0	1	9.57350E0005	3
2	****	69.323	5000.	-8.0	0	10533	8	3.46616E0005	19
3	****	44.586	5000.	7.0	0	500	3	2.22930E0005	5
4	****	36.015	54000.	12.0	0	268	1	1.94483E0006	3
5	****	84.718	720.	3.5	350	100	1	6.09970E0004	10
6	****	126.062	500.	4.0	500	500	1	6.30310E0004	10
7	****	42.737	10000.	8.0	0	2500	1	4.27374E0005	5
8	****	65.565	7000.	9.0	320	0	1	4.58956E0005	10
9	****	50.668	2000.	6.0	180	0	1	1.01336E0005	5
10	****	79.282	1700.	4.0	350	1200	1	1.34780E0005	11
11	****	224.588	1350.	4.0	400	1350	1	1.12294E0005	11
12	****	40.102	54000.	12.0	0	3005	3	2.16549E0006	7

File RSRVR 6/23/93 Page 1-2

row	O_U_MDFD	DUR_MDFD	DEVIATION
1	2	8103.	15
2	9	2981.	3
3	4	1097.	11
4	2	162755.	4
5	9	33.	27
6	9	55.	19
7	2	2981.	10
8	9	8103.	6
9	4	403.	22
10	9	55.	13
11	9	55.	33
12	4	162755.	4

PUMPING STATION DATA

File PUMP 6/23/93 Page 1-1

row	OBS	COST	RATE	NRML_CPCTY	NRML_HEAD	NO_PUMPS	FRWRD_TYPE
1	****	2.9315E0005	4653.127	63	24	5	1
2	****	5.9147E0005	717.806	824	164	2	0
3	****	7.7340E0005	773.399	1000	140	6	1
4	****	4.7360E0005	451.048	1050	110	3	1
5	****	8.0862E0004	175.787	460	65	2	1
6	****	1.9222E0006	565.353	3400	121	4	1

File PUMP 6/23/93 Page 1-2

row	CRANE_CPCT	SITE	ROCK	DURATION	DISTANCE	O_U
1	3	1	0	6	0	2
2	5	1	0	6	0	2
3	5	1	60	7	0	2
4	5	1	0	11	0	2
5	2	1	25	6	320	9
6	7	3	440	12	0	4

APPENDIX - B

DATA COLLECTION FORMS

PIPELINE DATA SHEET

PROJECT:	TYPE:
DATE:	DURATION:
CONTRACTOR:	GRADE:
CONSULTANT:	
INSTALLATION COST (RO):	ESCALATION FACTOR (%):
MATERIAL COST (RO):	ESCALATION FACTOR (%):
TOTAL ESCALATED COST (RO):	

	LENGTH OF PIPE (m) FOR DIFFERENT MATERIALS									
MTRL	DN 80	DN 100	DN 150	DN 200	DN 300	DN 450	DN 600	DN 800	DN 1000	TOTAL
AC										
DI										
TOTAL										

	LENGTH OF TRENCH (m) FOR DIFFERENT DEPTHS AND DIAMETERS									
MTRL	DN 80	DN 100	DN 150	DN 200	DN 300	DN 450	DN 600	DN 800	DN 1000	TOTAL
DPTH< 2 m										
2 m< DPTH 3.5 m										
TOTAL										

SITE			
EXCAVATED ROCK (m^3)		LENGTH OF ROAD X_ING (m):	
LENGTH OF WADI X_ING (m):		LOCATION:	
ACCESSIBILITY TO SITE:	1) EASY	2) MODERATE	3) DIFFICULT
TERRAIN:	1) FLAT	2) SEMI-HILLY	3) HILLY

RESERVOIR DATA SHEET

PROJECT:	TYPE:
DATE:	DURATION:
CONTRACTOR:	GRADE:
CONSULTANT:	
INSTALLATION COST (RO):	ESCALATION FACTOR (%):
MATERIAL COST (RO):	ESCALATION FACTOR (%):
TOTAL ESCALATED COST (RO):	

RESERVOIR
STORAGE CAPACITY ((m^3):

SITE			
EXCAVATED ROCK (m^3):			LOCATION:
ACCESSIBILITY TO SITE:	1) EASY	2) MODERATE	3) DIFFICULT

PUMPING STATION DATA SHEET

PROJECT:	TYPE:
DATE:	DURATION:
CONTRACTOR:	GRADE:
CONSULTANT:	
INSTALLATION COST (RO):	ESCALATION FACTOR (%):
MATERIAL COST (RO):	ESCALATION FACTOR (%):
TOTAL ESCALATED COST (RO):	

PUMPS	
NORMAL PUMPING CAPACITY ((m^3):	TYPE(F/B):
NORMAL PUMP'S HEAD (m):	
# OF PUMPS INSTALLED INCLUDING STDBY.:	
CAPACITY OF CRANE (ton):	

SITE			
EXCAVATED ROCK (m^3):		LOCATION:	
ACCESSIBILITY TO SITE:	1) EASY	2) MODERATE	3) DIFFICULT

APPENDIX - C

CORRELATION MATRICES

PIPELINE CORRELATION MATRIX

Wed Jun 23 1993 02:14:47 PM Page 1

Correlation matrix for coefficient estimates

	CONSTANT	PIPE.DIA	PIPE.DI	PIPE.DUR
CONSTANT	1.0000	.1384	-.0796	-.0697
PIPE.DIA	.1384	1.0000	-.2245	-.0374
PIPE.DI	-.0796	-.2245	1.0000	.1960
PIPE.DUR	-.0697	-.0374	.1960	1.0000
PIPE.DISTANCE	.2225	.6140	-.1832	.1693
PIPE.FLAT	-.5932	.1206	.1091	.2280
PIPE.SEMI_HILY	-.6397	-.0302	-.0380	.1767
PIPE.NO_CNGSTN	-.9097	-.2953	.0244	-.2000
PIPE.MID_CNGSTN	-.9377	-.2857	.0211	-.1513
PIPE.TRANS	-.1290	-.5646	-.3138	.2430
PIPE.ROAD_XING	-.3150	-.1612	.1060	-.0236
PIPE.WADI_XING	-.6490	-.6026	.0564	-.3342

	PIPE.DISTANCE	PIPE.FLAT	PIPE.SEMI_HILY	PIPE.NO_CNGSTN
CONSTANT	.2225	-.5932	-.6397	-.9097
PIPE.DIA	.6140	.1206	-.0302	-.2953
PIPE.DI	-.1832	.1091	-.0380	.0244
PIPE.DUR	.1693	.2280	.1767	-.2000
PIPE.DISTANCE	1.0000	-.0681	-.1388	-.3855
PIPE.FLAT	-.0681	1.0000	.8534	.2869
PIPE.SEMI_HILY	-.1388	.8534	1.0000	.3794
PIPE.NO_CNGSTN	-.3855	.2869	.3794	1.0000
PIPE.MID_CNGSTN	-.3568	.3852	.4787	.9772
PIPE.TRANS	-.2547	.0380	.2602	.0993
PIPE.ROAD_XING	-.0407	.0816	.1607	.3138
PIPE.WADI_XING	-.5493	.1426	.2262	.8226

	PIPE.MID_CNGSTN	PIPE.TRANS	PIPE.ROAD_XING	PIPE.WADI_XING
CONSTANT	-.9377	-.1290	-.3150	-.6490
PIPE.DIA	-.2857	-.5646	-.1612	-.6026
PIPE.DI	.0211	-.3138	.1060	.0564
PIPE.DUR	-.1513	.2430	-.0236	-.3342
PIPE.DISTANCE	-.3568	-.2547	-.0407	-.5493
PIPE.FLAT	.3852	.0380	.0816	.1426
PIPE.SEMI_HILY	.4787	.2602	.1607	.2262
PIPE.NO_CNGSTN	.9772	.0993	.3138	.8226
PIPE.MID_CNGSTN	1.0000	.1421	.2601	.7935
PIPE.TRANS	.1421	1.0000	.1219	.1787
PIPE.ROAD_XING	.2601	.1219	1.0000	.1440
PIPE.WADI_XING	.7935	.1787	.1440	1.0000

RESERVOIR CORRELATION MATRIX

Wed Jun 23 1993 02:22:32 PM

Page 1

Correlation matrix for coefficient estimates

	CONSTANT	RSRVR.CAPACITY	RSRVR.DURATION	RSRVR.DISTANCE
CONSTANT	1.0000	.5234	-.8923	-.8227
RSRVR.CAPACITY	.5234	1.0000	-.7930	-.1586
RSRVR.DURATION	-.8923	-.7930	1.0000	.5816
RSRVR.DISTANCE	-.8227	-.1586	.5816	1.0000
RSRVR.ROCK	.1255	-.0635	.0464	-.0880
RSRVR.SITE	-.2093	.1583	-.0739	.2306

	RSRVR.ROCK	RSRVR.SITE
CONSTANT	.1255	-.2093
RSRVR.CAPACITY	-.0635	.1583
RSRVR.DURATION	.0464	-.0739
RSRVR.DISTANCE	-.0880	.2306
RSRVR.ROCK	1.0000	-.9111
RSRVR.SITE	-.9111	1.0000

APPENDIX - D

APPLICATION EXAMPLE

SCREEN # 1

COMPUTERIZED CONCEPTUAL COST ESTIMATING SYSTEM
FOR DOMESTIC SUPPLY PROJECTS IN OMAN

DEVELOPED BY:
MASHHOOR AL-ASFOOR
AS A PARTIAL FULFILMENT FOR THE DEGREE OF

MASTER OF SCIENCE

IN
CONSTRUCTION ENGINEERING AND MANAGEMENT

COLLEGE OF ENVIRONMENTAL DESIGN
KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
DHAHRAN - SAUDI ARABIA
APRIL - 1993

PRESS ANY KEY TO CONTINUE ..

SCREEN # 2

COMPUTERIZED CONCEPTUAL COST ESTIMATING SYSTEM
FOR DOMESTIC SUPPLY PROJECTS IN OMAN

ESTIMATE THE COST OF:

PIPELINE.................................P

RESERVOIR R

PUMPING STATION S

EXIT X

ENTER YOUR CHOICE OF P, R, S, OR X

SCREEN # 3

PIPELINE COST MODEL

MENU

1. ESTIMATE THE COST OF A NEW PROJECT
2. RETREIVE EXISTING PROJECT
3. MAIN MENU

ENTER YOUR CHOICE OF P, R, S, OR X

SCREEN # 4

PIPELINE INPUT SESSION

A. GENERAL INFORMATION ABOUT THE PROJECT:

PROJECT NAME: ? MUSCAT WATER SUPPLY

LOCATION: ? MUSCAT

LENGTH OF PIPELINE (m): ? 18000

EXPECTED STARTING DATE: MONTH(mm)=? 8 YEAR (yyyy)=? 1995

DO YOU WANT TO ALTER YOUR INPUT (Y/N)?

SCREEN # 5

PIPELINE INPUT SESSION

B. PRIMARY FACTORS:

FACTOR #	FACTOR DESCRIPTION	VALUE
1	AVERGAE DIAMETER (mm)	? 1000
2	PERCENT OF DUCTILE IRON MATERIAL 'DI' (%)	? 100
3	LENGTH OF WADI CROSSING (m)	? 5000
4	EXPECTED PROJECT DURATION (MONTH)	? 12

DO YOU WANT TO ALTER YOUR INPUT (Y/N)?

SCREEN # 6

PIPELINE INPUT SESSION

B. OVER-UNDER FACTORS:

FACTOR #	FACTOR DESCRIPTION	VALUE
1	NUMBER OF RANGES FOR TRENCH DEPTH	? 4
2	NUMBER OF DIAMETER RANGES	? 1
3	GENERAL VICINITY OF SITE	? 3
4	SCHEME TYPE	? 1
5	DISTANCE FROM CONTRACTOR'S BASE TO PROJECT	? 1

DO YOU WANT TO ALTER YOUR INPUT (Y/N)?

SCREEN # 7

PIPELINE COST MODEL
OUTPUT MENU
1. DISPLAY OUTPUT
2. PRINT OUTPUT
3. DISPLAY INPUT
4. PIPELINE MENU
ENTER YOUR CHOICE OF 1, 2, 3, OR 4?

SCREEN # 8

PIPELINE OUTPUT SESSION

PROJECT: MUSCAT WATER SUPPLY
D. ESTIMATED TENDER PRICE:

	AVERAGE ANNUAL PRICE ESCALATION (%)*				
	2	2.5	3	3.5	4
** UNIT PRICE	316.57	320.60	324.65	328.74	332.86
*** TOTAL PRICE	5,698.2949	5,770,734	5,843,735	5,917,299	5,991,430

* AVERAGE ANNUAL PRICE ESCALATION OF INSTALLED PIPELINE SINCE JAN/1993
** ESTIMATED UNIT PRICE OF INSTALLED PIPELINE (± 4.6 RO/m)
*** ESTIMATED TOTAL PRICE OF TENDER (± 82800 RO/m)

PRESS ANY KEY TO CONTINUE.....

PIPELINE OUTPUT SESSION

A. GENERAL INFORMATION ABOUT THE PROJECT:

PROJECT NAME: MUSCAT WATER SUPPLY
LOCATION: MUSCAT
LENGTH OF PIPELINE (m): 18000
EXPECTED STARTING DATE: MONTH: 8 YEAR: 1995

B. PRIMARY FACTORS:

FACTOR	VALUE
1. AVERAGE DIAMETER (mm)	1000
2. PERCENT OF DUCTILE IRON 'DI' (%)	100
3. LENGTH OF WADI CROSSING (m)	5000
4. EXPECTED PROJECT DURATION (MONTH)	12

C. SECONDARY (O-U) FACTORS:

FACTOR	VALUE	COMMENT
1. NUMBER OF RANGES FOR TRENCH DEPTH	4	HILLY PROFILE
2. NUMBER OF DIAMETER RANGES	1	SIMPLE SCHEME
3. gENERAL VICINITY OF SITE	3	DIFFICULT/URBAN
4. SCHEME TYPE	1	TRANSMISSION
5. DISTANCE FROM CONTRACTOR'S BASE	1	<40 Km

D. ESTIMATED TENDER PRICE:

ANNUAL PRICE * ESCALATION (%)	UNIT RATE** (RO/m)	TOTAL PRICE*** (RO)
2	316.5719	5698294
2.5	320.5963	5770734
3	324.652	5843735
3.5	328.7389	5917299
4	332.8573	5991430

* AVERAGE ANNUAL PRICE ESCALATION OF INSTALLED PIPELINE SINCE JAN/1993
** ESTIMATED UNIT PRICE OF INSTALLED PIPELINE (± 4.6 RO/m)
*** ESTIMATED TOTAL PRICE OF TENDER (± 82800 RO/m)

APPENDIX - E

PROGRAM LISTING

```
5 REM    This program estimates the costs of domestic water supply projects
6 REM    in the Sultanate of Oman, it only produces conceptual estimating
7 REM    based on limited amount of information (June/1993)
10 COLOR 7,0:CLEAR:KEY OFF:CLS:COLOR 14,3
20 LOCATE 4,16:PRINT"COMPUTERIZED CONCEPTUAL COST
ESTIMATING SYSTEM (CCES)"
30 LOCATE 5,20:PRINT"FOR DOMESTIC WATER SUPPLY PROJECTS
IN OMAN"
40 COLOR 15,0:LOCATE 9 ,16:PRINT"            DEVELOPED BY:"
50 LOCATE 10,33:COLOR 15,0:PRINT" MASHHOOR AL-ASFOOR "
60 LOCATE 11,16:COLOR 15,0:PRINT"    AS A PARTIAL FULFILMENT
FOR THE DEGREE OF"
70 COLOR 12,0:LOCATE 13,34:PRINT" MASTER OF SCIENCE "
80 COLOR 15,0:LOCATE 15,16:PRINT"                 IN"
90 LOCATE 16,16:PRINT"     CONSTRUCTION ENGINEERING AND
MANAGEMENT"
100 LOCATE 18,16:PRINT"      COLLEGE OF ENVIRONMENTAL
DESIGN"
110 LOCATE 19,16:PRINT"   KING FAHD UNIVERSITY OF
PETROLEUM AND MINERALS"
120 LOCATE 20,16:PRINT"          DHAHRAN - SAUDI ARABIA"
130 LOCATE 21,16:PRINT"             APRIL - 1993"
140 PLAY "O3BB>CDDC<BA"
150 FOR I=1 TO 500:NEXT I
160 LOCATE 23,23:COLOR 10,0:PRINT"      PRESS ANY KEY TO
CONTINUE ..."
170 P$=INKEY$:IF P$="" THEN 170
180 KEY OFF:CLS:COLOR 14,3
190 LOCATE 3,20:PRINT"COMPUTERIZED CONCEPTUAL COST
ESTIMATING SYSTEM"
200 LOCATE 4,25:PRINT"FOR WATER SUPPLY PROJECTS IN
OMAN":COLOR 15,0
210 LOCATE  8,20:PRINT"    ESTIMATE THE COST OF:
220 LOCATE 11,20:PRINT"   PIPELINE ........................ P
230 LOCATE 13,20:PRINT"   RESERVOIR ........................ R
240 LOCATE 15,20:PRINT"   PUMPING STATION .................. S
250 LOCATE 17,20:PRINT"   EXIT ............................. X
```

```
260 COLOR 12,0:LOCATE 22,20:PRINT"    ENTER YOUR CHOICE OF P,
R, S, OR X"
270 A$=INKEY$:IF A$="" THEN 270
280 IF A$<>"P" AND A$<>"p" AND A$<>"R" AND A$<>"r" AND A$<>"S"
AND A$<>"s" AND A$<>"X" AND A$<>"x" THEN 270
290 IF A$="P" OR A$="p" THEN GOSUB 330
300 IF A$="R" OR A$="r" THEN GOSUB 3500
310 IF A$="S" OR A$="s" THEN GOSUB 6170
320 IF A$="X" OR A$="x" THEN CLS: LOCATE 15,30:PRINT"THANK
YOU FOR USING (CCES)":END
330 CLEAR:REM *********************** PIPELINE MODEL
**************************
340 COLOR 15,0:KEY OFF:CLS
350 LOCATE 1,20:COLOR 14,3:PRINT" P I P E L I N E   C O S T   M O D E
L "
360 LOCATE 6,35:PRINT"   M E N U  "
370 COLOR 15,0:LOCATE 8,24:PRINT"1. ESTIMATE THE COST OF A
NEW PROJECT
380 LOCATE 10,24:PRINT"2. RETREIVE EXISTING PROJECT
390 LOCATE 12,24:PRINT"3. MAIN MENU"
400 COLOR 12,0:LOCATE 15,25:PRINT"ENTER YOUR CHOICE; 1, 2, OR
3"
405 A$=INKEY$:IF A$="" THEN 405
410 IF A$<>"1" AND A$<>"2" AND A$<>"3" THEN 405
420 IF A$="1" THEN 450
430 IF A$="2" THEN 1370
440 IF A$="3" THEN 180
450 REM ******************** PIPELINE GENERAL INFORMATION
*****************
460 CLS:LOCATE 1,18:COLOR 14,3:PRINT"P I P E L I N E   I N P U T   S
E S S I O N
470 LOCATE 7,4:COLOR 14,3:PRINT"A. GENERAL INFORMATION
ABOUT THE PROJECT:
480 LOCATE 9,8:COLOR 15,0:PRINT"     PROJECT NAME:
490 LOCATE 11,8:PRINT "        LOCATION:
500 LOCATE 13,5:PRINT"LENGTH OF PIPELINE (m):
510 LOCATE 15,5:PRINT "EXPECTED STARTING DATE:
MONTH(mm)=      YEAR(yyyy)="
```

```
520 LOCATE 8,4:PRINT CHRS(201):FOR I=1 TO 70:LOCATE 8,4+I:PRINT
CHR$(205):NEXT I:LOCATE 8,4+I:PRINT CHR$(187)
530 LOCATE 16,4:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
16,4+I:PRINT CHR$(205):NEXT I:LOCATE 16,4+I:PRINT CHR$(188)
540 LOCATE 8,4:FOR I=1 TO 7:LOCATE 8+I,4:PRINT CHR$(186):NEXT I
550 LOCATE 8,75:FOR I=1 TO 7:LOCATE 8+I,75:PRINT
CHR$(186):NEXT I
560 LOCATE 9,29:COLOR 15,0:INPUT PRJCT$
570 LOCATE 11,28:INPUT PLACE$
580 LOCATE 13,28:INPUT LENGTH
581 IF LENGTH=>1 THEN 590
582 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
LENGTH MUST BE =>1m, HIT ANY KEY TO CONTINUE"
583 A$=INKEY$: IF A$="" THEN 583
584 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 580
590 LOCATE 15,41:INPUT STMONTH
591 IF STMONTH=>1 AND STMONTH=<12 THEN 600
592 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
MONTH IS OUT OF RANGE (1-12 ONLY), HIT ANY KEY TO
CONTINUE"
593 A$=INKEY$: IF A$="" THEN 593
594 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 590
600 LOCATE 15,60:INPUT STYEAR
601 IF STYEAR=>1993 THEN 610
602 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
YEAR MUST BE =>1993, HIT ANY KEY TO CONTINUE"
603 A$=INKEY$: IF A$="" THEN 603
604 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 600
610 LOCATE 21,6:COLOR 11,14:PRINT"DO YOU WANT TO ALTER
YOUR INPUT (Y/N)"
615 A$=INKEY$:IF A$="" THEN 615
620 LOCATE 21,6:COLOR 7,0:PRINT"                    "
630 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 610
640 IF A$="Y" OR A$="y" THEN 560
650 REM *************** PIPELINE PRIMARY FACTORS
*************************
```

```
660 CLS:COLOR 14,3:LOCATE 1,20:PRINT"P I P E L I N E  I N P U T  S
E S S I O N
670 LOCATE 4,3:COLOR 14,3:PRINT"B. PRIMARY FACTORS:
680 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR          FACTOR
DESCRIPTION              VALUE
690 LOCATE 7,6:PRINT"#
700 FOR I=1 TO 4
710 LOCATE 8+2*I,5:PRINT I
720 NEXT I
730 LOCATE 10,14:PRINT"AVERAGE DIAMETER (mm)
740 LOCATE 12,14:PRINT"PERCENT OF DUCTILE IRON MATERIAL 'DI'
(%)
750 LOCATE 14,14:PRINT"LENGTH OF WADI CROSSING (m)
760 LOCATE 16,14:PRINT"EXPECTED PROJECT DURATION (MONTH)
770 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE 5,3+I:PRINT
CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
780 LOCATE 17,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
17,3+I:PRINT CHR$(205):NEXT I:LOCATE 17,3+I:PRINT CHR$(188)
790 LOCATE 5,3:FOR I=1 TO 11:LOCATE 5+I,3:PRINT CHR$(186):NEXT
I
800 LOCATE 5,74:FOR I=1 TO 11:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
810 LOCATE 5,11:FOR I=1 TO 11:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
820 LOCATE 5,64:FOR I=1 TO 11:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
830 LOCATE 8,3:PRINT CHR$(204):FOR I=1 TO 70:LOCATE 8,3+I:PRINT
CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
840 LOCATE 5,11:PRINT CHR$(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHR$(206):LOCATE 8,64:PRINT
CHR$(206):LOCATE 17,11:PRINT CHR$(202):LOCATE 17,64:PRINT
CHR$(202)
850 LOCATE 10,66:COLOR 15,0:INPUT DIA
851 IF DIA=>100 AND DIA =<1000 THEN 860
852 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
DIAMETER IS OUT OF RANGE (100mm-1000mm ONLY), HIT ANY KEY
TO CONTINUE"
853 A$=INKEY$: IF A$="" THEN 853
```

```
854 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 850
860 LOCATE 12,66:INPUT DI
861 IF DI=>0 AND DI=<100 THEN 870
862 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT IS
OUT OF RANGE (0%-100% ONLY), HIT ANY KEY TO CONTINUE"
863 A$=INKEY$: IF A$="" THEN 863
864 COLOR 15,0:LOCATE 20,6:PRINT"
":GOTO 860
870 LOCATE 14,66:INPUT WXING
871 IF WXING=>0 AND WXING=<5800 THEN 880
872 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
WADI CROSSING IS OUT OF RANGE (0m-5800m ONLY), HIT ANY KEY
TO CONTINUE"
873 A$=INKEY$: IF A$="" THEN 873
874 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 870
880 LOCATE 16,66:INPUT DUR
881 IF DUR=>2 AND DUR =<12 THEN 890
882 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
DURATION IS OUT OF RANGE (2months-12months ONLY), HIT ANY
KEY TO CONTINUE"
883 A$=INKEY$: IF A$="" THEN 883
884 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 880
890 LOCATE 21,6:COLOR 11,14:PRINT"DO YOU WANT TO ALTER
YOUR INPUT (Y/N)"
895 A$=INKEY$:IF A$="" THEN 895
900 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 890
910 LOCATE 21,6:COLOR 7,0:PRINT"                              "
920 IF A$="Y" OR A$="y" THEN 850
930 REM ********************* PIPELINE SECONDARY (O-U)
FACTORS ****************
940 CLS:COLOR 14,3:LOCATE 1,20:PRINT"P I P E L I N E  I N P U T  S
E S S I O N
950 LOCATE 4,3:COLOR 14,3:PRINT"C. OVER-UNDER FACTORS:
960 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR            FACTOR
DESCRIPTION             VALUE
970 LOCATE 7,6:PRINT"#
```

```
980 FOR I=1 TO 5
990 LOCATE 8+2*I,5:PRINT I
1000 NEXT I
1010 LOCATE 10,12:PRINT"NUMBER OF RANGES FOR TRENCH
DEPTH
1020 LOCATE 12,12:PRINT"NUMBER OF DIAMETER RANGES
1030 LOCATE 14,12:PRINT"GENERAL VICINITY OF SITE
1040 LOCATE 16,12:PRINT"SCHEME TYPE
1050 LOCATE 18,12:PRINT"DISTANCE FROM CONTRACTOR'S BASE
TO PROJECT
1060 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
5,3+I:PRINT CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
1070 LOCATE 19,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
19,3+I:PRINT CHR$(205):NEXT I:LOCATE 19,3+I:PRINT CHR$(188)
1080 LOCATE 5,3:FOR I=1 TO 13:LOCATE 5+I,3:PRINT
CHR$(186):NEXT I
1090 LOCATE 5,74:FOR I=1 TO 13:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
1100 LOCATE 5,11:FOR I=1 TO 13:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
1110 LOCATE 5,64:FOR I=1 TO 13:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
1120 LOCATE 8,3:PRINT CHR$(204):FOR I=1 TO 70:LOCATE
8,3+I:PRINT CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
1130 LOCATE 5,11:PRINT CHR$(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHR$(206):LOCATE 8,64:PRINT
CHR$(206):LOCATE 19,11:PRINT CHR$(202):LOCATE 19,64:PRINT
CHR$(202)
1140 LOCATE 21,6:COLOR 10,0:PRINT"THIS FACTOR IS ASSESING
THE PROFILE OF THE PIPELINE ROUTE    "
1150 LOCATE 23,6:PRINT"FLAT:1-2    SEMI-HILLY:3    HILLY:>3
"
1160 LOCATE 10,66:COLOR 15,0:INPUT TRCHRANGE
1161 IF TRCHRANGE=>1 THEN 1170
1162 COLOR 15,0:LOCATE 21,6:PRINT"
"
1163 LOCATE 22,6:PRINT"
"
```

```
1164 BEEP:COLOR 11,14:LOCATE 22,6:PRINT"WARNING ... INPUT
MUST BE >1, HIT ANY KEY TO CONTINUE"
1165 A$=INKEY$: IF A$="" THEN 1165
1166 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 1140
1170 LOCATE 21,6:COLOR 10,0:PRINT"HOW MANY OF THESE
DIAMETER RANGES FIT THE PROJECT SCHEME?   "
1180 LOCATE 23,6:PRINT"D<100, 100<D<200, 200<D<300, 300<D<600,
600<D<900, 900<D<1200"
1190 LOCATE 12,66:COLOR 15,0:INPUT DIARANGE
1191 IF DIARANGE=>1 THEN 1200
1192 COLOR 15,0:LOCATE 21,6:PRINT"
"
1193 LOCATE 22,6:PRINT"
"
1194 BEEP:COLOR 11,14:LOCATE 22,6:PRINT"WARNING ... INPUT
MUST BE >0, HIT ANY KEY TO CONTINUE"
1195 A$=INKEY$: IF A$="" THEN 1195
1196 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 1170
1200 LOCATE 21,6:COLOR 10,0:PRINT"WHAT IS THE GENERAL
VICINITY OF THE PROJECT'S SITE?        "
1210 LOCATE 23,6:PRINT"1.EASY/RURAL   2.MODERATE/SUBURBAN
3.DIFFICULT/URBAN    "
1220 LOCATE 14,66:COLOR 15,0:INPUT SITE
1221 IF SITE=>1 AND SITE =<3 THEN 1230
1222 COLOR 15,0:LOCATE 21,6:PRINT"
"
1223 LOCATE 22,6:PRINT"
"
1224 BEEP:COLOR 11,14:LOCATE 22,6:PRINT"WARNING ... INPUT
RANGE IS 1-3 ONLY, HIT ANY KEY TO CONTINUE"
1225 A$=INKEY$: IF A$="" THEN 1225
1226 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 1200
1230 LOCATE 21,6:COLOR 10,0:PRINT"WHAT IS THE SCHEME TYPE
OF PIPELINE?                "
1240 LOCATE 23,6:PRINT"1.TRANSMISSION   2.DISTRIBUTION
FEEDER              "
```

```
1250 LOCATE 16,66:COLOR 15,0:INPUT TYPE
1251 IF TYPE=1 OR TYP=2 THEN 1260
1252 COLOR 15,0:LOCATE 21,6:PRINT"
"
1253 LOCATE 22,6:PRINT"
"
1254 BEEP:COLOR 11,14:LOCATE 22,6:PRINT"WARNING ... INPUT
RANGE IS 1-2 ONLY, HIT ANY KEY TO CONTINUE"
1255 A$=INKEY$: IF A$="" THEN 1255
1256 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 1230
1260 LOCATE 21,6:COLOR 10,0:PRINT"HOW FAR IS THE PROJECT
FROM THE CONTARACTOR'S BASE?        "
1270 LOCATE 23,6:PRINT"1. <40 km     2. <250 km     3. >250 km
"
1280 LOCATE 18,66:COLOR 15,0:INPUT DIST
1281 IF DIST=>1 AND DIST=<3 THEN 1290
1282 COLOR 15,0:LOCATE 21,6:PRINT"
"
1283 LOCATE 22,6:PRINT"
"
1284 BEEP:COLOR 11,14:LOCATE 22,6:PRINT"WARNING ... INPUT
RANGE IS 1-3 ONLY, HIT ANY KEY TO CONTINUE"
1285 A$=INKEY$: IF A$="" THEN 1285
1286 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 1260
1290 LOCATE 21,6:COLOR 11,14:PRINT"DO YOU WANT TO ALTER
YOUR INPUT (Y/N) ":LOCATE 21,44:COLOR 7,0:PRINT"
":LOCATE 23,6:PRINT"                              ":COLOR 11,14:LOCATE
21,43
1295 A$=INKEY$:IF A$="" THEN 1295
1300 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 1290
1310 LOCATE 21,6:COLOR 7,0:PRINT"                              "
1320 IF A$="Y" OR A$="y" THEN 1140
1321 LOCATE 22,6:COLOR 11,14:PRINT"DO YOU WANT TO SAVE
YOUR INPUT (Y/N)  ":LOCATE 21,44:COLOR 7,0:PRINT"
":LOCATE 23,6:PRINT"                              ":COLOR 11,14:LOCATE
21,43
1322 A$="":A$=INKEY$:IF A$="" THEN 1322
```

```
1323 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 1322
1324 IF A$="N" OR A$="n" THEN 1420
1326 LOCATE 23,6:INPUT"ENTER FILE NAME (</= 6
CHARACTERS):";F$
1327 F$=F$+".PIP"
1330 REM *************** STORING PIPELINE DATA
*************************
1331 COLOR 7,0
1340 OPEN "O",1,F$
1350 WRITE #1, PRJCT$, PLACE$, LENGTH, STMONTH, STYEAR, DIA,
DI, WXING, DUR, TRCHRANGE, DIARANGE, SITE, TYPE, DIST
1360 CLOSE #1:GOTO 1420
1370 REM *************** RETRIEVING PIPELINE DATA
*************************
1380 CLEAR:CLS:COLOR 7,0
1381 LOCATE 3,1:PRINT"EXISTING PIPELINE PROJECTS:"
1382 FILES"*.PIP"
1383 LOCATE 22,1:INPUT"INPUT PROJECT NAME TO RETREIVE <9 to
exit>:";F$
1384 IF F$="9" THEN 330
1385 F$=F$+".PIP"
1386 OPEN "I",1,F$
1390 INPUT #1, PRJCT$, PLACE$, LENGTH, STMONTH, STYEAR, DIA,
DI, WXING, DUR, TRCHRANGE, DIARANGE, SITE, TYPE, DIST
1400 IF EOF(1) THEN 1410
1410 CLOSE #1
1420 REM ****************** CALCULATION OF THE PIPELINE
COST **************
1430 IF SITE=1 THEN SITE1=1
1440 IF SITE=2 THEN SITE1=3
1450 IF SITE=3 THEN SITE1=8
1460 IF TYPE=1 THEN TYPE1=1
1470 IF TYPE=2 THEN TYPE1=3
1480 IF DIST=1 THEN DIST1=1
1490 IF DIST=2 THEN DIST1=3
1500 IF DIST=3 THEN DIST1=8
1510
OVRUNDR=TRCHRANGE*.5+DIARANGE*.5+SITE1+TYPE1+DIST1
```

```
1520 RATE=11.553358#+.000256*(DIA^2)+.09594*DI-
1.3222521#*DUR+.005603*WXING+.919127*OVRUNDR
1530 REM *************** PIPELINE OUTPUT MENU
*********************************
1540 COLOR 7,0:CLS:LOCATE 1,20:COLOR 14,3:PRINT" P I P E L I N E
C O S T   M O D E L"
1550 LOCATE 6,28:PRINT" O U T P U T   M E N U  "
1560 COLOR 15,0:LOCATE 8,31:PRINT"1. DISPLAY OUTPUT
1570 LOCATE 10,31:PRINT"2. PRINT OUTPUT
1580 LOCATE 12,31:PRINT"3. DISPLAY INPUT
1590 LOCATE 14,31:PRINT"4. PIPELINE MENU
1600 COLOR 12,0:LOCATE 17,25:PRINT"ENTER YOUR CHOICE; 1, 2, 3
OR 4"
1605 A$=INKEY$:IF A$="" THEN 1605
1610 IF A$<>"1" AND A$<>"2" AND A$<>"3" AND A$<>"4" THEN 1605
1620 IF A$="1" THEN GOSUB 2450
1630 IF A$="2" THEN GOSUB 2870
1640 IF A$="3" THEN GOSUB 1680
1650 IF A$="4" THEN GOTO 330
1660 GOTO 1540
1670 COLOR 7,0:KEY OFF:CLS
1680 REM ******************* PIPELINE GENERAL INFORMATION
*****************
1690 CLS:LOCATE 1,18:COLOR 14,3:PRINT"P I P E L I N E   O U T P U T
S E S S I O N
1700 LOCATE 7,18:COLOR 14,3:PRINT"A. GENERAL INFORMATION
ABOUT THE PROJECT:
1710 LOCATE 9,8:COLOR 15,0:PRINT"      PROJECT NAME:
1720 LOCATE 11,8:PRINT "        LOCATION:
1730 LOCATE 13,5:PRINT"LENGTH OF PIPELINE (m):
1740 LOCATE 15,5:PRINT "EXPECTED STARTING DATE:
MONTH(mm)=       YEAR(yyyy)="
1750 LOCATE 8,4:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
8,4+I:PRINT CHR$(205):NEXT I:LOCATE 8,4+I:PRINT CHR$(187)
1760 LOCATE 16,4:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
16,4+I:PRINT CHR$(205):NEXT I:LOCATE 16,4+I:PRINT CHR$(188)
1770 LOCATE 8,4:FOR I=1 TO 7:LOCATE 8+I,4:PRINT CHR$(186):NEXT
I
```

```
1780 LOCATE 8,75:FOR I=1 TO 7:LOCATE 8+I,75:PRINT
CHR$(186):NEXT I
1790 LOCATE 9,29:COLOR 15,0:PRINT PRJCT$
1800 LOCATE 11,29:PRINT PLACE$
1810 LOCATE 13,29:PRINT LENGTH
1820 LOCATE 15,41:PRINT STMONTH
1830 LOCATE 15,60:PRINT STYEAR
1840 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE ....."
1850 A$=INKEY$:IF A$="" THEN 1850
1860 COLOR 7,0
1870 REM ************** PIPELINE PRIMARY FACTORS
*************************
1880 CLS:COLOR 14,3:LOCATE 1,20:PRINT"P I P E L I N E  O U T P U T
S E S S I O N
1890 LOCATE 4,4:COLOR 14,3:PRINT"B. PRIMARY FACTORS:
1900 LOCATE 3,4:COLOR 15,1:PRINT"PROJECT: ";PRJCT$
1910 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR          FACTOR
DESCRIPTION                    VALUE
1920 LOCATE 7,6:PRINT"#
1930 FOR I=1 TO 4
1940 LOCATE 8+2*I,5:PRINT I
1950 NEXT I
1960 LOCATE 10,14:PRINT"AVERAGE DIAMETER (mm)
1970 LOCATE 12,14:PRINT"PERCENT OF DUCTILE IRON MATERIAL
'DI' (%)
1980 LOCATE 14,14:PRINT"LENGTH OF WADI CROSSING (m)
1990 LOCATE 16,14:PRINT"EXPECTED PROJECT DURATION (MONTH)
2000 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
5,3+I:PRINT CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
2010 LOCATE 17,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
17,3+I:PRINT CHR$(205):NEXT I:LOCATE 17,3+I:PRINT CHR$(188)
2020 LOCATE 5,3:FOR I=1 TO 11:LOCATE 5+I,3:PRINT
CHR$(186):NEXT I
2030 LOCATE 5,74:FOR I=1 TO 11:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
2040 LOCATE 5,11:FOR I=1 TO 11:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
```

```
2050 LOCATE 5,64:FOR I=1 TO 11:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
2060 LOCATE 8,3:PRINT CHR$(204):FOR I=1 TO 70:LOCATE
8,3+I:PRINT CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
2070 LOCATE 5,11:PRINT CHR$(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHR$(206):LOCATE 8,64:PRINT
CHR$(206):LOCATE 17,11:PRINT CHR$(202):LOCATE 17,64:PRINT
CHR$(202)
2080 LOCATE 10,66:COLOR 15,0:PRINT DIA
2090 LOCATE 12,66:PRINT DI
2100 LOCATE 14,66:PRINT WXING
2110 LOCATE 16,66:PRINT DUR
2120 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE ....."
2130 A$=INKEY$:IF A$="" THEN 2130
2140 COLOR 7,0
2150 REM ******************* PIPELINE SECONDARY (O-U)
FACTORS ****************
2160 CLS:COLOR 14,3:LOCATE 1,20:PRINT"P I P E L I N E  O U T P U T
S E S S I O N
2170 LOCATE 4,4:COLOR 14,3:PRINT"C. OVER-UNDER FACTORS:
2180 LOCATE 3,4:COLOR 15,1:PRINT"PROJECT: ";PRJCT$
2190 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR            FACTOR
DESCRIPTION                VALUE
2200 LOCATE 7,6:PRINT"#
2210 FOR I=1 TO 5
2220 LOCATE 8+2*I,5:PRINT I
2230 NEXT I
2240 LOCATE 10,12:PRINT"NUMBER OF RANGES FOR TRENCH
DEPTH
2250 LOCATE 12,12:PRINT"NUMBER OF DIAMETER RANGES
2260 LOCATE 14,12:PRINT"GENERAL VICINITY OF SITE
2270 LOCATE 16,12:PRINT"SCHEME TYPE
2280 LOCATE 18,12:PRINT"DISTANCE FROM CONTRACTOR'S BASE
TO PROJECT
2290 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
5,3+I:PRINT CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
2300 LOCATE 19,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
19,3+I:PRINT CHR$(205):NEXT I:LOCATE 19,3+I:PRINT CHR$(188)
```

```
2310 LOCATE 5,3:FOR I=1 TO 13:LOCATE 5+I,3:PRINT
CHR$(186):NEXT I
2320 LOCATE 5,74:FOR I=1 TO 13:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
2330 LOCATE 5,11:FOR I=1 TO 13:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
2340 LOCATE 5,64:FOR I=1 TO 13:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
2350 LOCATE 8,3:PRINT CHRS(204):FOR I=1 TO 70:LOCATE
8,3+I:PRINT CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
2360 LOCATE 5,11:PRINT CHRS(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHR$(206):LOCATE 8,64:PRINT
CHR$(206):LOCATE 19,11:PRINT CHR$(202):LOCATE 19,64:PRINT
CHR$(202)
2370 LOCATE 10,66:COLOR 15,0:PRINT TRCHRANGE
2380 LOCATE 12,66:COLOR 15,0:PRINT DIARANGE
2390 LOCATE 14,66:COLOR 15,0:PRINT SITE
2400 LOCATE 16,66:COLOR 15,0:PRINT TYPE
2410 LOCATE 18,66:COLOR 15,0:PRINT DIST
2420 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE ....."
2430 A$=INKEY$:IF A$="" THEN 2430:COLOR 7,0
2440 COLOR 7,0:RETURN
2450 REM ************* PIPELINE ESTIMATED TENDER PRICES
*********************
2460 CLS:COLOR 14,3:LOCATE 1,20:PRINT"P I P E L I N E   O U T P U T
S E S S I O N
2470 LOCATE 4,4:COLOR 14,3:PRINT"D. ESTIMATED TENDER PRICE:"
2480 LOCATE 3,4:COLOR 15,1:PRINT"PROJECT: ";PRJCT$:LOCATE
3,53:PRINT"CONST. DATE: ";STMONTH;"/";STYEAR
2490 COLOR 15,0:LOCATE 5,16:FOR I=1 TO 60:LOCATE 5,16+I:PRINT
CHR$(205):NEXT I
2500 LOCATE 7,16:FOR I=1 TO 60:LOCATE 7,16+I:PRINT
CHR$(205):NEXT I
2510 LOCATE 9,4:FOR I=1 TO 72:LOCATE 9,4+I:PRINT
CHR$(205):NEXT I
2520 LOCATE 12,4:FOR I=1 TO 72:LOCATE 12,4+I:PRINT
CHR$(205):NEXT I
```

```
2530 LOCATE 15,4:FOR I=1 TO 72:LOCATE 15,4+I:PRINT
CHR$(205):NEXT I
2540 LOCATE 9,4:FOR I=1 TO 5:LOCATE 9+I,4:PRINT CHR$(186):NEXT
I
2550 LOCATE 5,16:FOR I=1 TO 9:LOCATE 5+I,16:PRINT
CHR$(186):NEXT I
2560 LOCATE 8,22:PRINT"2         2.5         3         3.5         4
2570 FOR J=28 TO 64 STEP 12:LOCATE 7,J:FOR I=1 TO 7:LOCATE
7+I,J:PRINT CHR$(186):NEXT I:NEXT J
2580 LOCATE 5,76:FOR I=1 TO 9:LOCATE 5+I,76:PRINT
CHR$(186):NEXT I
2590 LOCATE 9,4:PRINT CHR$(201):LOCATE 12,4:PRINT
CHR$(204):LOCATE 15,4:PRINT CHR$(200)
2600 LOCATE 5,16:PRINT CHR$(201):LOCATE 5,76:PRINT
CHR$(187):LOCATE 7,16:PRINT CHR$(204):LOCATE 7,76:PRINT
CHR$(185):LOCATE 9,76:PRINT CHR$(185):LOCATE 12,76:PRINT
CHR$(185):LOCATE 15,76:PRINT CHR$(188)
2610 FOR I=16 TO 64 STEP 12:LOCATE 15,I:PRINT CHR$(202):NEXT I
2620 FOR I=28 TO 64 STEP 12:LOCATE 7,I:PRINT CHR$(203):NEXT I
2630 FOR I=9 TO 12 STEP 3:FOR J=16 TO 64 STEP 12:LOCATE I,J:PRINT
CHR$(206):NEXT J:NEXT I
2640 LOCATE 6,30:PRINT"AVERAGE ANNUAL PRICE ESCALATION
(%)":COLOR 2,0:LOCATE 6,66:PRINT"*":COLOR 7,0
2650 COLOR 2,0:LOCATE 10,14:PRINT"**":LOCATE 13,13:PRINT
"***":COLOR 15,0
2660 LOCATE 11,5:PRINT"UNIT PRICE":LOCATE 14,5:PRINT"TOTAL
PRICE"
2670 COLOR 2,0:LOCATE 17,4:PRINT"* AVERAGE ANNUAL PRICE
ESCALATION OF INSTALLED PIPELINE SINCE JAN/1993."
2680 LOCATE 18,3:PRINT"** ESTIMATED UNIT PRICE OF INSTALLED
PIPELINE (";CHR$(241);" 4.6 RO/m)"
2690 LOCATE 19,2:PRINT"*** ESTIMATED TOTAL PRICE OF TENDER
(";CHR$(241);" ";INT(4.6*LENGTH);" RO)":COLOR 7,0
2700 REM *************** PIPELINE FILLING THE TABLE OF FINAL
ANSWER*******
2710 COLOR 3,0
2720 TIMDIFF=(STYEAR-1993)+((STMONTH-1)/12)    ' CALCULATING
TIME DIFFERENCE
2730 COL=9
```

```
2740 FOR I=2 TO 4 STEP .5
2750 COL=COL+12
2760 ESCRATE=RATE*(1+(I/100))^TIMDIFF
2770 LOCATE 11,COL:PRINT USING "###.##";ESCRATE
2780 NEXT I
2790 COL=5
2800 FOR I=2 TO 4 STEP .5
2810 COL=COL+12
2820 ESCPRICE=(RATE*LENGTH)*(1+(I/100))^TIMDIFF
2830 LOCATE 14,COL:PRINT USING "##,###,###";ESCPRICE
2840 NEXT I
2850 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE .....":A$=INKEY$:IF A$="" THEN 2850
2860 COLOR 7,0:RETURN
2870 REM ****************** PIPELINE PRINT OUTPUT
******************
2880 LPRINT"          P I P E L I N E   O U T P U T   S E S S I O
N":LPRINT:LPRINT:LPRINT:LPRINT
2890 LPRINT"A. GENERAL INFORMATION ABOUT THE PROJECT:
2900
LPRINT"_______________________________________________________
__"
2910 LPRINT"        PROJECT NAME:";PRJCT$
2920 LPRINT"            LOCATION:";PLACE$
2930 LPRINT"LENGTH OF PIPELINE (m):";LENGTH
2940 LPRINT"EXPECTED STARTING DATE:     MONTH:";STMONTH;"
YEAR:";STYEAR
2950
LPRINT"_______________________________________________________
__"
2960 LPRINT:LPRINT:LPRINT:LPRINT
2970 LPRINT"B. PRIMARY FACTORS:"
2980
LPRINT"_______________________________________________________
__"
2990 LPRINT"      FACTOR                            VALUE
3000
LPRINT"_______________________________________________________
__"
```

```
3010 LPRINT"1. AVERAGE DIAMETER (mm)";TAB(49);DIA
3020 LPRINT"2. PERCENT OF DUCTILE IRON MATERIAL 'DI'
(%)";TAB(49);DI
3030 LPRINT"3. LENGTH OF WADI CROSSING (m)";TAB(49);WXING
3040 LPRINT"4. EXPECTED PROJECT DURATION
(MONTH)";TAB(49);DUR
3050
LPRINT"____________________________________________________________
 "
__
3060 LPRINT:LPRINT:LPRINT:LPRINT
3070 IF TRCHRANGE=<2 THEN CMNT1$="FLAT PROFILE"
3080 IF TRCHRANGE=3 THEN CMNT1$="SEMI HILLY PROFILE"
3090 IF TRCHRANGE>3 THEN CMNT1$="HILLY PROFILE"
3100 IF DIARANGE=<3 THEN CMNT2$="SIMPLE SCHEME"
3110 IF DIARANGE=4 THEN CMNT2$="SEMI COMPLEX SCHEME"
3120 IF DIARANGE>4 THEN CMNT2$="COMPLEX SCHEME"
3130 IF SITE=1 THEN CMNT3S="EASY/RURAL"
3140 IF SITE=2 THEN CMNT3S="MODERATE/SUBURBAN"
3150 IF SITE=3 THEN CMNT3S="DIFFICULT/URBAN"
3160 IF TYPE=1 THEN CMNT4S="TRANSMISSION"
3170 IF TYPE=2 THEN CMNT4S="DISTRIBUTION"
3180 IF DIST=1 THEN CMNT5S="<40 Km"
3190 IF DIST=2 THEN CMNT5S="<250 Km"
3200 IF DIST=3 THEN CMNT5S=">250 Km"
3210 LPRINT"C. SECONDARY (O-U) FACTORS:"
3220
LPRINT"____________________________________________________________
______________"
3230 LPRINT"     FACTOR                    VALUE     COMMENT"
3240
LPRINT"____________________________________________________________
________________"
3250 LPRINT"1. NUMBER OF RANGES FOR TRENCH
DEPTH";TAB(49);TRCHRANGE;TAB(58);CMNT1$
3260 LPRINT"2. NUMBER OF DIAMETER
RANGES";TAB(49);DIARANGE;TAB(58);CMNT2$
3270 LPRINT"3. GENERAL VICINITY OF
SITE";TAB(49);SITE;TAB(58);CMNT3$
```

```
3280 LPRINT"4. SCHEME
TYPE";TAB(49);TAB(49);TYPE;TAB(58);CMNT4$
3290 LPRINT"5. DISTANCE FROM CONTRACTOR'S BASE TO
PROJECT";TAB(49);DIST;TAB(58);CMNT5$
3300
LPRINT"______________________________________________________
________________"
3310 LPRINT:LPRINT:LPRINT:LPRINT
3320 LPRINT"D. ESTIMATED TENDER PRICE:"
3330
LPRINT"______________________________________________________
_____"
3340 LPRINT" ANNUAL PRICE *          UNIT RATE **    TOTAL
PRICE ***
3350 LPRINT"ESCALATION (%)            (RO/m)          (RO)
3360
LPRINT"______________________________________________________
_____"
3370 TIMDIFF=(STYEAR-1993)+((STMONTH-1)/12)
3380 DIM ESCRATE(5),ESCPRICE(5)
3390 FOR I=2 TO 4 STEP .5
3400 ESCRATE(I)=RATE*(1+(I/100))^TIMDIFF
3410 ESCPRICE(I)=(RATE*LENGTH)*(1+(I/100))^TIMDIFF
3420 LPRINT TAB(7);I;TAB(30);ESCRATE(I);TAB(48);ESCPRICE(I)
3430 NEXT I
3440
LPRINT"______________________________________________________
_____"
3450 LPRINT
3460 LPRINT"  * AVERGAE ANNUAL PRICE ESCALATION OF
INSTALLED PIPELINE SINCE JAN/1993"
3470 LPRINT" ** ESTIMATED UNIT PRICE OF INSTALLED PIPELINE
(+/- 4.6 RO/m)"
3480 LPRINT"*** ESTIMATED TOTAL PRICE OF TENDER (+/-
";4.6*LENGTH;"RO)"
3490 RETURN
3500 CLS:COLOR 7,0:CLEAR:REM ************ RESERVOIR MODEL
********************
3510 COLOR 15,0:KEY OFF:CLS
```

```
3520 LOCATE 1,20:COLOR 14,3:PRINT" R E S E R V O I R   C O S T   M
O D E L"
3530 LOCATE 6,35:PRINT"    M E N U  "
3540 COLOR 15,0:LOCATE 8,24:PRINT"1. ESTIMATE THE COST OF A
NEW PROJECT
3550 LOCATE 10,24:PRINT"2. RETREIVE EXISTING PROJECT
3560 LOCATE 12,24:PRINT"3. MAIN MENU"
3570 COLOR 12,0:LOCATE 15,25:PRINT"ENTER YOUR CHOICE; 1, 2,
OR 3"
3575 A$=INKEY$:IF A$="" THEN 3575
3580 IF A$<>"1" AND A$<>"2" AND A$<>"3" THEN 3570
3590 IF A$="1" THEN 3620
3600 IF A$="2" THEN 4360
3610 IF A$="3" THEN 180
3620 REM ****************** RESERVOIR GENERAL
INFORMATION ****************
3630 CLS:LOCATE 1,18:COLOR 14,3:PRINT"R E S E R V O I R   I N P U T
S E S S I O N
3640 LOCATE 7,4:COLOR 14,3:PRINT"A. GENERAL INFORMATION
ABOUT THE PROJECT:
3650 LOCATE 9,8:COLOR 15,0:PRINT"      PROJECT NAME:
3660 LOCATE 11,8:PRINT "          LOCATION:
3670 LOCATE 13,5:PRINT "EXPECTED STARTING DATE:
MONTH(mm)=        YEAR(yyyy)="
3680 LOCATE 8,4:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
8,4+I:PRINT CHR$(205):NEXT I:LOCATE 8,4+I:PRINT CHR$(187)
3690 LOCATE 14,4:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
14,4+I:PRINT CHR$(205):NEXT I:LOCATE 14,4+I:PRINT CHR$(188)
3700 LOCATE 8,4:FOR I=1 TO 5:LOCATE 8+I,4:PRINT CHR$(186):NEXT
I
3710 LOCATE 8,75:FOR I=1 TO 5:LOCATE 8+I,75:PRINT
CHR$(186):NEXT I
3720 LOCATE 9,29:COLOR 15,0:INPUT PRJCT$
3730 LOCATE 11,28:INPUT PLACE$
3740 LOCATE 13,41:INPUT STMONTH
3741 IF STMONTH=>1 AND STMONTH=<12 THEN 3750
3742 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OUT
OF RANGE (1-12 ONLY), HIT ANY KEY TO CONTINUE"
3743 A$=INKEY$: IF A$="" THEN 3743
```

```
3744 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 3740
3750 LOCATE 13,60:INPUT STYEAR
3751 IF STYEAR=>1993 THEN 3760
3752 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
YEAR MUST BE =>1993, HIT ANY KEY TO CONTINUE"
3753 A$=INKEY$: IF A$="" THEN 3753
3754 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 3750
3760 LOCATE 21,6:COLOR 11,14:PRINT"DO YOU WANT TO ALTER
YOUR INPUT (Y/N)"
3765 A$=INKEY$:IF A$="" THEN 3765
3770 LOCATE 21,6:COLOR 7,0:PRINT"                    "
3780 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 3760
3790 IF A$="Y" OR A$="y" THEN 3720
3800 REM ****************** RESERVOIR PRIMARY FACTORS
**************************
3810 CLS:COLOR 14,3:LOCATE 1,20:PRINT"R E S E R V O I R  I N P U T
S E S S I O N
3820 LOCATE 4,3:COLOR 14,3:PRINT"B. PRIMARY FACTORS:
3830 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR          FACTOR
DESCRIPTION                    VALUE
3840 LOCATE 7,6:PRINT"#
3850 FOR I=1 TO 2
3860 LOCATE 8+2*I,5:PRINT I
3870 NEXT I
3880 LOCATE 10,14:PRINT"STORING CAPACITY OF RESERVOIR (m3)"
3890 LOCATE 12,14:PRINT"EXPECTED PROJECT DURATION (MONTH)
3900 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
5,3+I:PRINT CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
3910 LOCATE 13,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
13,3+I:PRINT CHR$(205):NEXT I:LOCATE 13,3+I:PRINT CHR$(188)
3920 LOCATE 5,3:FOR I=1 TO 7:LOCATE 5+I,3:PRINT CHR$(186):NEXT
I
3930 LOCATE 5,74:FOR I=1 TO 7:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
3940 LOCATE 5,11:FOR I=1 TO 7:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
```

```
3950 LOCATE 5,64:FOR I=1 TO 7:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
3960 LOCATE 8,3:PRINT CHR$(204):FOR I=1 TO 70:LOCATE
8,3+I:PRINT CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
3970 LOCATE 5,11:PRINT CHR$(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHR$(206):LOCATE 8,64:PRINT
CHR$(206):LOCATE 13,11:PRINT CHR$(202):LOCATE 13,64:PRINT
CHR$(202)
3980 LOCATE 10,66:COLOR 15,0:INPUT CAPACITY
3981 IF CAPACITY=>500 AND CAPACITY=<54000! THEN 3990
3982 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
CAPACITY IS OUT OF RANGE (500m3-54000m3 ONLY), HIT ANY KEY
TO CONTINUE"
3983 A$=INKEY$: IF A$="" THEN 3983
3984 COLOR 15,0:LOCATE 22,1:PRINT"
":GOTO 3980
3990 LOCATE 12,66:INPUT DUR
3991 IF DUR=>3 AND DUR=<12 THEN 4000
3992 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
DURATION IS OUT OF RANGE (3-12months ONLY), HIT ANY KEY TO
CONTINUE"
3993 A$=INKEY$: IF A$="" THEN 3993
3994 COLOR 15,0:LOCATE 22,1:PRINT"
":GOTO 3990
4000 LOCATE 21,6:COLOR 11,14:PRINT"DO YOU WANT TO ALTER
YOUR INPUT (Y/N)"
4005 A$=INKEY$: IF A$="" THEN 4005
4010 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 4000
4020 LOCATE 21,6:COLOR 7,0:PRINT"                              "
4030 IF A$="Y" OR A$="y" THEN 3980
4040 REM ******************** RESERVOIR SECONDARY (O-U)
FACTORS ****************
4050 CLS:COLOR 14,3:LOCATE 1,20:PRINT"R E S E R V O I R   I N P U T
S E S S I O N
4060 LOCATE 4,3:COLOR 14,3:PRINT"C. OVER-UNDER FACTORS:
4070 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR          FACTOR
DESCRIPTION                VALUE
4080 LOCATE 7,6:PRINT"#
4090 FOR I=1 TO 2
```

```
4100 LOCATE 8+2*I,5:PRINT I
4110 NEXT I
4120 LOCATE 10,12:PRINT"GENERAL VICINITY OF SITE
4130 LOCATE 12,12:PRINT"DISTANCE FROM CONTRACTOR'S BASE
TO PROJECT
4140 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
5,3+I:PRINT CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
4150 LOCATE 13,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
13,3+I:PRINT CHR$(205):NEXT I:LOCATE 13,3+I:PRINT CHR$(188)
4160 LOCATE 5,3:FOR I=1 TO 7:LOCATE 5+I,3:PRINT CHR$(186):NEXT
I
4170 LOCATE 5,74:FOR I=1 TO 7:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
4180 LOCATE 5,11:FOR I=1 TO 7:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
4190 LOCATE 5,64:FOR I=1 TO 7:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
4200 LOCATE 8,3:PRINT CHR$(204):FOR I=1 TO 70:LOCATE
8,3+I:PRINT CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
4210 LOCATE 5,11:PRINT CHR$(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHR$(206):LOCATE 8,64:PRINT
CHR$(206):LOCATE 13,11:PRINT CHR$(202):LOCATE 13,64:PRINT
CHR$(202)
4220 LOCATE 21,6:COLOR 10,0:PRINT"WHAT IS THE GENERAL
VICINITY OF THE PROJECT'S SITE?        "
4230 LOCATE 23,6:PRINT"1.EASY/RURAL   2.MODERATE/SUBURBAN
3.DIFFICULT/URBAN    "
4240 LOCATE 10,66:COLOR 15,0:INPUT SITE
4241 IF SITE=>1 AND SITE =<3 THEN 4250
4242 COLOR 15,0:LOCATE 21,6:PRINT"
"
4243 LOCATE 22,6:PRINT"
"
4244 BEEP:COLOR 11,14:LOCATE 22,6:PRINT"WARNING ... INPUT
RANGE IS 1-3 ONLY, HIT ANY KEY TO CONTINUE"
4245 A$=INKEY$: IF A$="" THEN 4245
4246 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 4220
```

```
4250 LOCATE 21,6:COLOR 10,0:PRINT"HOW FAR IS THE PROJECT
FROM THE CONTARACTOR'S BASE?        "
4260 LOCATE 23,6:PRINT"1. <40 km     2. <250 km     3. >250 km
"
4270 LOCATE 12,66:COLOR 15,0:INPUT DIST
4271 IF DIST=>1 AND DIST=<3 THEN 4280
4272 COLOR 15,0:LOCATE 21,6:PRINT"
"
4273 LOCATE 22,6:PRINT"
"
4274 BEEP:COLOR 11,14:LOCATE 22,6:PRINT"WARNING ... INPUT
RANGE IS 1-3 ONLY, HIT ANY KEY TO CONTINUE"
4275 A$=INKEY$: IF A$="" THEN 4275
4276 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 4250
4280 LOCATE 21,6:COLOR 11,14:PRINT"DO YOU WANT TO ALTER
YOUR INPUT (Y/N) ":LOCATE 21,44:COLOR 7,0:PRINT"
":LOCATE 23,6:PRINT"                              ":COLOR 11,14:LOCATE
21,43
4285 A$=INKEY$:IF A$="" THEN 4285
4290 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 4280
4300 LOCATE 21,6:COLOR 7,0:PRINT"                              "
4310 IF A$="Y" OR A$="y" THEN 4040
4311 LOCATE 22,6:COLOR 11,14:PRINT"DO YOU WANT TO SAVE
YOUR INPUT (Y/N)  ":LOCATE 21,44:COLOR 7,0:PRINT"
":LOCATE 23,6:PRINT"                              ":COLOR 11,14:LOCATE
21,43
4312 A$="":A$=INKEY$:IF A$="" THEN 4312
4313 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 4312
4314 IF A$="N" OR A$="n" THEN 4410
4316 LOCATE 23,6:INPUT"ENTER FILE NAME (</= 6
CHARACTERS):";F$
4317 F$=F$+".RSR"
4320 REM *************** STORING RESERVOIR DATA
*************************
4330 COLOR 7,0
4340 OPEN "O",1,F$
4350 WRITE #1, PRJCT$, PLACES, STMONTH, STYEAR, CAPACITY,
DUR, SITE, DIST
```

```
4351 CLOSE #1:GOTO 4410
4360 REM *************** RETRIEVING RESERVOIR DATA
*************************
4370 CLEAR:CLS:COLOR 7,0
4371 LOCATE 3,1:PRINT"EXISTING RESERVOIR PROJECTS:"
4372 FILES"*.RSR"
4373 LOCATE 22,1:INPUT"INPUT PROJECT NAME TO RETREIVE <9 to
exit>:";F$
4374 IF F$="9" THEN 330
4375 F$=F$+".RSR"
4376 OPEN "I",1,F$
4380 INPUT #1, PRJCT$, PLACE$, STMONTH, STYEAR, CAPACITY,
DUR, SITE, DIST
4390 IF EOF(1) THEN 4400
4400 CLOSE #1
4410 REM ****************** CALCULATION OF THE RESERVOIR
COST **************
4420 IF SITE=1 THEN SITE1=1
4430 IF SITE=2 THEN SITE1=3
4440 IF SITE=3 THEN SITE1=8
4450 IF DIST=1 THEN DIST1=1
4460 IF DIST=2 THEN DIST1=3
4470 IF DIST=3 THEN DIST1=8
4480 OVRUNDR=SITE1+DIST1
4490 PRICE=(-210736.2) + (64.80223*CAPACITY) - (8.094229*EXP(DUR))
+ (28218.006379#*OVRUNDR):COLOR 7,0
4500 REM******** RESERVOIR OUTPUT MENU
*******************************
4510 CLS:LOCATE 1,20:COLOR 14,3:PRINT" R E S E R V O I R  C O S T
M O D E L "
4520 LOCATE 6,28:PRINT"  O U T P U T   M E N U  "
4530 COLOR 15,0:LOCATE 8,31:PRINT"1. DISPLAY OUTPUT
4540 LOCATE 10,31:PRINT"2. PRINT OUTPUT
4550 LOCATE 12,31:PRINT"3. DISPLAY INPUT
4560 LOCATE 14,31:PRINT"4. RESERVOIR MENU
4570 COLOR 12,0:LOCATE 17,25:PRINT"ENTER YOUR CHOICE; 1, 2, 3
OR 4"
4575 A$=INKEY$:IF A$="" THEN 4575
4580 IF A$<>"1" AND A$<>"2" AND A$<>"3" AND A$<>"4" THEN 4570
```

```
4590 IF A$="1" THEN GOSUB 5300
4600 IF A$="2" THEN GOSUB 5680
4610 IF A$="3" THEN GOSUB 4650
4620 IF A$="4" THEN GOTO 3500
4630 GOTO 4510
4640 COLOR 7,0:KEY OFF:CLS
4650 REM ***************************** GENERAL INFORMATION
*****************
4660 CLS:LOCATE 1,18:COLOR 14,3:PRINT"R E S E R V O I R  O U T P
U T  S E S S I O N
4670 LOCATE 7,18:COLOR 14,3:PRINT"A. GENERAL INFORMATION
ABOUT THE PROJECT:
4680 LOCATE 9,8:COLOR 15,0:PRINT"      PROJECT NAME:
4690 LOCATE 11,8:PRINT "          LOCATION:
4700 LOCATE 13,5:PRINT "EXPECTED STARTING DATE:
MONTH(mm)=      YEAR(yyyy)="
4710 LOCATE 8,4:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
8,4+I:PRINT CHR$(205):NEXT I:LOCATE 8,4+I:PRINT CHR$(187)
4720 LOCATE 14,4:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
14,4+I:PRINT CHR$(205):NEXT I:LOCATE 14,4+I:PRINT CHR$(188)
4730 LOCATE 8,4:FOR I=1 TO 5:LOCATE 8+I,4:PRINT CHR$(186):NEXT
I
4740 LOCATE 8,75:FOR I=1 TO 5:LOCATE 8+I,75:PRINT
CHR$(186):NEXT I
4750 LOCATE 9,29:COLOR 15,0:PRINT PRJCT$
4760 LOCATE 11,29:PRINT PLACE$
4770 LOCATE 13,41:PRINT STMONTH
4780 LOCATE 13,60:PRINT STYEAR
4790 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE ....."
4800 A$=INKEY$:IF A$="" THEN 4800
4810 COLOR 7,0
4820 REM **************** RESERVOIR PRIMARY FACTORS
************************
4830 CLS:COLOR 14,3:LOCATE 1,20:PRINT"R E S E R V O I R  O U T P
U T  S E S S I O N
4840 LOCATE 4,4:COLOR 14,3:PRINT"B. PRIMARY FACTORS:
4850 LOCATE 3,4:COLOR 15,1:PRINT"PROJECT: ";PRJCT$
```

```
4860 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR           FACTOR
DESCRIPTION              VALUE
4870 LOCATE 7,6:PRINT"#
4880 FOR I=1 TO 2
4890 LOCATE 8+2*I,5:PRINT I
4900 NEXT I
4910 LOCATE 10,14:PRINT"STORING CAPACITY OF RESERVOIR (m3)
4920 LOCATE 12,14:PRINT"EXPECTED PROJECT DURATION (MONTH)
4930 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
5,3+I:PRINT CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
4940 LOCATE 13,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
13,3+I:PRINT CHR$(205):NEXT I:LOCATE 13,3+I:PRINT CHR$(188)
4950 LOCATE 5,3:FOR I=1 TO 7:LOCATE 5+I,3:PRINT CHR$(186):NEXT
I
4960 LOCATE 5,74:FOR I=1 TO 7:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
4970 LOCATE 5,11:FOR I=1 TO 7:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
4980 LOCATE 5,64:FOR I=1 TO 7:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
4990 LOCATE 8,3:PRINT CHR$(204):FOR I=1 TO 70:LOCATE
8,3+I:PRINT CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
5000 LOCATE 5,11:PRINT CHR$(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHRS(206):LOCATE 8,64:PRINT
CHR$(206):LOCATE 13,11:PRINT CHR$(202):LOCATE 13,64:PRINT
CHR$(202)
5010 LOCATE 10,66:COLOR 15,0:PRINT CAPACITY
5020 LOCATE 12,66:PRINT DUR
5030 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE ....."
5040 A$=INKEY$:IF A$="" THEN 5040
5050 COLOR 7,0
5060 REM ******************** RESERVOIR SECONDARY (O-U)
FACTORS ****************
5070 CLS:COLOR 14,3:LOCATE 1,20:PRINT"R E S E R V O I R  O U T P
U T  S E S S I O N
5080 LOCATE 4,4:COLOR 14,3:PRINT"C. OVER-UNDER FACTORS:
5090 LOCATE 3,4:COLOR 15,1:PRINT"PROJECT: ";PRJCT$
```

```
5100 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR            FACTOR
DESCRIPTION               VALUE
5110 LOCATE 7,6:PRINT"#
5120 FOR I=1 TO 2
5130 LOCATE 8+2*I,5:PRINT I
5140 NEXT I
5150 LOCATE 10,12:PRINT"GENERAL VICINITY OF SITE
5160 LOCATE 12,12:PRINT"DISTANCE FROM CONTRACTOR'S BASE
TO PROJECT
5170 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
5,3+I:PRINT CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
5180 LOCATE 13,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
13,3+I:PRINT CHR$(205):NEXT I:LOCATE 13,3+I:PRINT CHR$(188)
5190 LOCATE 5,3:FOR I=1 TO 7:LOCATE 5+I,3:PRINT CHR$(186):NEXT
I
5200 LOCATE 5,74:FOR I=1 TO 7:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
5210 LOCATE 5,11:FOR I=1 TO 7:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
5220 LOCATE 5,64:FOR I=1 TO 7:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
5230 LOCATE 8,3:PRINT CHR$(204):FOR I=1 TO 70:LOCATE
8,3+I:PRINT CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
5240 LOCATE 5,11:PRINT CHR$(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHR$(206):LOCATE 8,64:PRINT
CHR$(206):LOCATE 13,11:PRINT CHR$(202):LOCATE 13,64:PRINT
CHR$(202)
5250 LOCATE 10,66:COLOR 15,0:PRINT SITE
5260 LOCATE 12,66:COLOR 15,0:PRINT DIST
5270 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE ....."
5280 A$=INKEY$:IF A$="" THEN 5280:COLOR 7,0
5290 COLOR 7,0:RETURN
5300 REM *************** RESERVOIR ESTIMATED TENDER PRICES
*********************
5310 CLS:COLOR 14,3:LOCATE 1,20:PRINT"R E S E R V O I R  O U T P
U T  S E S S I O N
5320 LOCATE 4,4:COLOR 14,3:PRINT"D. ESTIMATED TENDER PRICE:"
```

```
5330 LOCATE 3,4:COLOR 15,1:PRINT"PROJECT: ";PRJCT$:LOCATE
3,53:PRINT"CONST. DATE: ";STMONTH;"/";STYEAR
5340 COLOR 15,0:LOCATE 5,16:FOR I=1 TO 60:LOCATE 5,16+I:PRINT
CHR$(205):NEXT I
5350 LOCATE 7,16:FOR I=1 TO 60:LOCATE 7,16+I:PRINT
CHR$(205):NEXT I
5360 LOCATE 9,4:FOR I=1 TO 72:LOCATE 9,4+I:PRINT
CHR$(205):NEXT I
5370 LOCATE 12,4:FOR I=1 TO 72:LOCATE 12,4+I:PRINT
CHR$(205):NEXT I
5380 LOCATE 15,4:FOR I=1 TO 72:LOCATE 15,4+I:PRINT
CHR$(205):NEXT I
5390 LOCATE 9,4:FOR I=1 TO 5:LOCATE 9+I,4:PRINT CHR$(186):NEXT
I
5400 LOCATE 5,16:FOR I=1 TO 9:LOCATE 5+I,16:PRINT
CHR$(186):NEXT I
5410 LOCATE 8,22:PRINT"1         1.5         2         2.5         3
5420 FOR J=28 TO 64 STEP 12:LOCATE 7,J:FOR I=1 TO 7:LOCATE
7+I,J:PRINT CHR$(186):NEXT I:NEXT J
5430 LOCATE 5,76:FOR I=1 TO 9:LOCATE 5+I,76:PRINT
CHR$(186):NEXT I
5440 LOCATE 9,4:PRINT CHR$(201):LOCATE 12,4:PRINT
CHR$(204):LOCATE 15,4:PRINT CHR$(200)
5450 LOCATE 5,16:PRINT CHR$(201):LOCATE 5,76:PRINT
CHR$(187):LOCATE 7,16:PRINT CHR$(204):LOCATE 7,76:PRINT
CHR$(185):LOCATE 9,76:PRINT CHR$(185):LOCATE 12,76:PRINT
CHR$(185):LOCATE 15,76:PRINT CHR$(188)
5460 FOR I=16 TO 64 STEP 12:LOCATE 15,I:PRINT CHR$(202):NEXT I
5470 FOR I=28 TO 64 STEP 12:LOCATE 7,I:PRINT CHR$(203):NEXT I
5480 FOR I=9 TO 12 STEP 3:FOR J=16 TO 64 STEP 12:LOCATE I,J:PRINT
CHR$(206):NEXT J:NEXT I
5490 LOCATE 6,30:PRINT"AVERAGE ANNUAL PRICE ESCALATION
(%)":COLOR 2,0:LOCATE 6,66:PRINT"*":COLOR 7,0
5500 COLOR 2,0:LOCATE 10,14:PRINT"**":LOCATE 13,13:PRINT
"***":COLOR 15,0
5510 LOCATE 11,5:PRINT"UNIT PRICE":LOCATE 14,5:PRINT"TOTAL
PRICE"
5520 COLOR 2,0:LOCATE 17,4:PRINT"* AVERAGE ANNUAL PRICE
ESCALATION OF CONSTRUCTED RESERVOIR SINCE JAN/1993."
```

```
5530 LOCATE 18,3:PRINT"** ESTIMATED UNIT PRICE OF
CONSTRUCTED RESERVOIR
(";CHR$(241);33656.25/CAPACITY;"RO/m3)"
5540 LOCATE 19,2:PRINT"*** ESTIMATED TOTAL PRICE OF TENDER
(";CHR$(241);" 33656 RO)":COLOR 7,0
5550 REM ************ RESERVOIR FILLING THE TABLE OF FINAL
ANSWER************
5560 COLOR 3,0
5570 TIMDIFF=(STYEAR-1993)+((STMONTH-1)/12)    ' CALCULATING
TIME DIFFERENCE
5580 COL=5
5590 FOR I=1 TO 3 STEP .5
5600 COL=COL+12
5610 ESCPRICE=PRICE*(1+(I/100))^TIMDIFF
5620 ESCRATE=ESCPRICE/CAPACITY
5630 LOCATE 14,COL:PRINT USING "##,###,###";ESCPRICE
5640 LOCATE 11,COL+4:PRINT USING "###.##";ESCRATE
5650 NEXT I
5660 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE .....":A$=INKEY$:IF A$="" THEN 5660
5670 COLOR 7,0:RETURN
5680 REM ********************** RESERVOIR PRINT OUTPUT
******************
5690 LPRINT"        R E S E R V O I R  O U T P U T  S E S S I O
N":LPRINT:LPRINT:LPRINT:LPRINT
5700 LPRINT"A. GENERAL INFORMATION ABOUT THE PROJECT:
5710
LPRINT"______________________________________________________
_"
5720 LPRINT"        PROJECT NAME:";PRJCT$
5730 LPRINT"            LOCATION:";PLACE$
5740 LPRINT"EXPECTED STARTING DATE:    MONTH:";STMONTH;"
YEAR:";STYEAR
5750
LPRINT"______________________________________________________
_"
5760 LPRINT:LPRINT:LPRINT:LPRINT
5770 LPRINT"B. PRIMARY FACTORS:"
```

```
5780
LPRINT"________________________________________________________
 "
5790 LPRINT"     FACTOR                          VALUE
5800
LPRINT"________________________________________________________
 "
5810 LPRINT"1. STORING CAPACITY OF RESERVOIR
(m3)";TAB(49);CAPACITY
5820 LPRINT"2. EXPECTED PROJECT DURATION
(MONTH)";TAB(49);DUR
5830
LPRINT"________________________________________________________
 "
5840 LPRINT:LPRINT:LPRINT:LPRINT
5850 IF SITE=1 THEN CMNT3$="EASY/RURAL"
5860 IF SITE=2 THEN CMNT3$="MODERATE/SUBURBAN"
5870 IF SITE=3 THEN CMNT3$="DIFFICULT/URBAN"
5880 IF DIST=1 THEN CMNT5$="<40 Km"
5890 IF DIST=2 THEN CMNT5$="<250 Km"
5900 IF DIST=3 THEN CMNT5$=">250 Km"
5910 LPRINT"C. SECONDARY (O-U) FACTORS:"
5920
LPRINT"________________________________________________________
________________"
5930 LPRINT"     FACTOR                          VALUE      COMMENT"
5940
LPRINT"________________________________________________________
________________"
5950 LPRINT"1. GENERAL VICINITY OF
SITE";TAB(49);SITE;TAB(58);CMNT3$
5960 LPRINT"2. DISTANCE FROM CONTRACTOR'S BASE TO
PROJECT";TAB(49);DIST;TAB(58);CMNT5$
5970
LPRINT"________________________________________________________
________________"
5980 LPRINT:LPRINT:LPRINT:LPRINT
5990 LPRINT"D. ESTIMATED TENDER PRICE:"
```

```
6000
LPRINT"_______________________________________________________
_____"
6010 LPRINT" ANNUAL PRICE *          UNIT RATE **    TOTAL
PRICE ***
6020 LPRINT"ESCALATION (%)          (RO/m3)         (RO)
6030
LPRINT"_______________________________________________________
_____"
6040 TIMDIFF=(STYEAR-1993)+((STMONTH-1)/12)
6050 DIM ESCRATE(5),ESCPRICE(5)
6060 FOR I=1 TO 3 STEP .5
6070 ESCPRICE(I)=PRICE*(1+(I/100))^TIMDIFF
6080 ESCRATE(I)=ESCPRICE(I)/CAPACITY
6090 LPRINT TAB(7);I;TAB(30);ESCRATE(I);TAB(48);ESCPRICE(I)
6100 NEXT I
6110
LPRINT"_______________________________________________________
_____"
6120 LPRINT
6130 LPRINT"  * AVERGAE ANNUAL PRICE ESCALATION OF
CONSTRUCTED RESERVOIR SINCE JAN/1993"
6140 LPRINT" ** ESTIMATED UNIT PRICE OF CONSTRUCTED
RESERVOIR (+/- ";33656!/CAPACITY;" RO/m3)"
6150 LPRINT"*** ESTIMATED TOTAL PRICE OF TENDER (+/- 33656
RO)
6160 RETURN
6170 CLEAR:REM ************** PUMPING STATION MODEL
**************************
6180 COLOR 15,0:KEY OFF:CLS
6190 LOCATE 1,20:COLOR 14,3:PRINT" P U M P I N G   S T A T I O N  C
O S T   M O D E L"
6200 LOCATE 6,35:PRINT"    M E N U  "
6210 COLOR 15,0:LOCATE 8,24:PRINT"1. ESTIMATE THE COST OF A
NEW PROJECT
6220 LOCATE 10,24:PRINT"2. RETREIVE EXISTING PROJECT
6230 LOCATE 12,24:PRINT"3. MAIN MENU"
6240 COLOR 12,0:LOCATE 15,25:PRINT"ENTER YOUR CHOICE; 1, 2,
OR 3"
```

```
6245 A$=INKEY$:IF A$="" THEN 6245
6250 IF A$<>"1" AND A$<>"2" AND A$<>"3" THEN 6240
6260 IF A$="1" THEN 6290
6270 IF A$="2" THEN 6810
6280 IF A$="3" THEN 180
6290 REM **************** PUMPING STATION GENERAL
INFORMATION *****************
6300 CLS:LOCATE 1,18:COLOR 14,3:PRINT"P U M P I G   S T A T I O N
I N P U T   S E S S I O N
6310 LOCATE 7,4:COLOR 14,3:PRINT"A. GENERAL INFORMATION
ABOUT THE PROJECT:
6320 LOCATE 9,8:COLOR 15,0:PRINT"      PROJECT NAME:
6330 LOCATE 11,8:PRINT "          LOCATION:
6340 LOCATE 13,5:PRINT "EXPECTED STARTING DATE:
MONTH(mm)=       YEAR(yyyy)="
6350 LOCATE 8,4:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
8,4+I:PRINT CHR$(205):NEXT I:LOCATE 8,4+I:PRINT CHR$(187)
6360 LOCATE 14,4:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
14,4+I:PRINT CHR$(205):NEXT I:LOCATE 14,4+I:PRINT CHR$(188)
6370 LOCATE 8,4:FOR I=1 TO 5:LOCATE 8+I,4:PRINT CHR$(186):NEXT
I
6380 LOCATE 8,75:FOR I=1 TO 5:LOCATE 8+I,75:PRINT
CHR$(186):NEXT I
6390 LOCATE 9,29:COLOR 15,0:INPUT PRJCT$
6400 LOCATE 11,28:INPUT PLACE$
6410 LOCATE 13,41:INPUT STMONTH
6411 IF STMONTH=>1 AND STMONTH=<12 THEN 6420
6412 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OUT
OF RANGE (1-12 ONLY), HIT ANY KEY TO CONTINUE"
6413 A$=INKEY$: IF A$="" THEN 6413
6414 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 6410
6420 LOCATE 13,60:INPUT STYEAR
6421 IF STYEAR=>1993 THEN 6430
6422 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
YEAR MUST BE =>1993, HIT ANY KEY TO CONTINUE"
6423 A$=INKEY$: IF A$="" THEN 6423
6424 COLOR 15,0:LOCATE 21,6:PRINT"
":GOTO 6420
```

```
6430 LOCATE 21,6:COLOR 11,14:PRINT"DO YOU WANT TO ALTER
YOUR INPUT (Y/N)"
6435 A$=INKEY$: IF A$="" THEN 6435
6440 LOCATE 21,6:COLOR 7,0:PRINT"                              "
6450 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 6430
6460 IF A$="Y" OR A$="y" THEN 6390
6470 REM ********** PUMPING STATION PRIMARY FACTORS
*************************
6480 CLS:COLOR 14,3:LOCATE 1,20:PRINT"P U M P I G   S T A T I O N
I N P U T   S E S S I O N
6490 LOCATE 4,3:COLOR 14,3:PRINT"B. PRIMARY FACTORS:
6500 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR          FACTOR
DESCRIPTION                VALUE
6510 LOCATE 7,6:PRINT"#
6520 FOR I=1 TO 5
6530 LOCATE 8+2*I,5:PRINT I
6540 NEXT I
6550 LOCATE 10,14:PRINT"NORMAL PUMPING CAPACITY (m3/HOUR)
6560 LOCATE 12,14:PRINT"NORMAL OPERATING HEAD (m)
6570 LOCATE 14,14:PRINT"TYPE OF PUMPING STATION
(FORWARD=1  BOOSTER=0)
6580 LOCATE 16,14:PRINT"CRANE CAPACITY (TON)
6590 LOCATE 18,14:PRINT"EXPECTED PROJECT DURATION (MONTH)
6600 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
5,3+I:PRINT CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
6610 LOCATE 19,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
19,3+I:PRINT CHR$(205):NEXT I:LOCATE 19,3+I:PRINT CHR$(188)
6620 LOCATE 5,3:FOR I=1 TO 13:LOCATE 5+I,3:PRINT
CHR$(186):NEXT I
6630 LOCATE 5,74:FOR I=1 TO 13:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
6640 LOCATE 5,11:FOR I=1 TO 13:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
6650 LOCATE 5,64:FOR I=1 TO 13:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
6660 LOCATE 8,3:PRINT CHR$(204):FOR I=1 TO 70:LOCATE
8,3+I:PRINT CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
6670 LOCATE 5,11:PRINT CHR$(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHR$(206):LOCATE 8,64:PRINT
```

```
CHR$(206):LOCATE 19,11:PRINT CHR$(202):LOCATE 19,64:PRINT
CHR$(202)
6680 LOCATE 10,66:COLOR 15,0:INPUT CAPACITY
6681 IF CAPACITY=>60 AND CAPACITY=<3400 THEN 6690
6682 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
CAPACITY IS OUT OF RANGE (60m3/Hr-3400m3/Hr ONLY), HIT ANY
KEY TO CONTINUE"
6683 A$=INKEY$: IF A$="" THEN 6683
6684 COLOR 15,0:LOCATE 22,1:PRINT"
":GOTO 6680
6690 LOCATE 12,66:INPUT HEAD
6691 IF HEAD=>25 AND HEAD=<165 THEN 6700
6692 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
HEAD IS OUT OF RANGE (25m-165m ONLY), HIT ANY KEY TO
CONTINUE"
6693 A$=INKEY$: IF A$="" THEN 6693
6694 COLOR 15,0:LOCATE 22,1:PRINT"
":GOTO 6690
6700 LOCATE 14,66:INPUT TYPE
6701 IF TYPE=0 OR TYPE=1 THEN 6710
6702 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
TYPE IS OUT OF RANGE (0 OR 1 ONLY), HIT ANY KEY TO
CONTINUE"
6703 A$=INKEY$: IF A$="" THEN 6703
6704 COLOR 15,0:LOCATE 22,1:PRINT"
":GOTO 6700
6710 LOCATE 16,66:INPUT CRANE
6711 IF CRANE=>2 AND CRANE=<7 THEN 6720
6712 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
CRANE CAPACITY IS OUT OF RANGE (2-7 tons ONLY), HIT ANY KEY
TO CONTINUE"
6713 A$=INKEY$: IF A$="" THEN 6713
6714 COLOR 15,0:LOCATE 22,1:PRINT"
":GOTO 6710
6720 LOCATE 18,66:INPUT DUR
6721 IF DUR=>6 AND DUR=<12 THEN 6730
6722 BEEP:LOCATE 21,6:COLOR 11,14:PRINT"WARNING.. INPUT OF
DURATION IS OUT OF RANGE (6-12months ONLY), HIT ANY KEY TO
CONTINUE"
```

```
6723 A$=INKEY$: IF A$="" THEN 6723
6724 COLOR 15,0:LOCATE 22,1:PRINT"
":GOTO 6720
6730 LOCATE 21,6:COLOR 11,14:PRINT"DO YOU WANT TO ALTER
YOUR INPUT (Y/N)"
6735 A$=INKEY$:IF A$="" THEN 6735
6740 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 6730
6750 LOCATE 21,6:COLOR 7,0:PRINT"                                    "
6760 IF A$="Y" OR A$="y" THEN 6680
6761 LOCATE 22,6:COLOR 11,14:PRINT"DO YOU WANT TO SAVE
YOUR INPUT (Y/N)  ":LOCATE 21,44:COLOR 7,0:PRINT"
":LOCATE 23,6:PRINT"                              ":COLOR 11,14:LOCATE
21,43
6762 A$="":A$=INKEY$:IF A$="" THEN 6762
6763 IF A$<>"Y" AND A$<>"y" AND A$<>"N" AND A$<>"n" THEN 6762
6764 IF A$="N" OR A$="n" THEN 6860
6766 LOCATE 23,6:INPUT"ENTER FILE NAME (</= 6
CHARACTERS):";F$
6767 F$=F$+".PMP"
6770 REM *************** STORING PUMPING STATION DATA
*************************
6771 COLOR 7,0
6780 OPEN "O",1,F$
6790 WRITE #1, PRJCT$, PLACE$, STMONTH, STYEAR, CAPACITY,
HEAD, TYPE, CRANE, DUR
6800 CLOSE #1:GOTO 6860
6810 REM *************** RETRIEVING PUMPING STATION DATA
********************
6820 CLEAR:CLS:COLOR 7,0
6821 LOCATE 3,1:PRINT"EXISTING PUMPING STATION PROJECTS:"
6822 FILES"*.PMP"
6823 LOCATE 22,1:INPUT"INPUT PROJECT NAME TO RETREIVE <9 to
exit>:";F$
6824 IF F$="9" THEN 330
6825 F$=F$+".PMP"
6826 OPEN "I",1,F$
6830 INPUT #1, PRJCT$, PLACE$, STMONTH, STYEAR, CAPACITY,
HEAD, TYPE, CRANE, DUR
6840 IF EOF(1) THEN 6850
```

```
6850 CLOSE #1
6860 REM ****************** CALCULATION OF THE PUMPING STATION COST ***********
6870 PRICE= 45521.975646# + (451.795927#*CAPACITY) - (3142.479568#*HEAD) - (104165.8*DUR) + (131157.2*TYPE) + (262806.3*CRANE)'
6880 REM *************** PUMPING STATION OUTPUT MENU **************************
6890 COLOR 7,0:CLS:LOCATE 1,20:COLOR 14,3:PRINT" P U M P I N G S T A T I O N   C O S T   M O D E L"
6900 LOCATE 6,28:PRINT" O U T P U T   M E N U  "
6910 COLOR 15,0:LOCATE 8,31:PRINT"1. DISPLAY OUTPUT
6920 LOCATE 10,31:PRINT"2. PRINT OUTPUT
6930 LOCATE 12,31:PRINT"3. DISPLAY INPUT
6940 LOCATE 14,31:PRINT"4. PUMPING STATION MENU
6950 COLOR 12,0:LOCATE 17,25:PRINT"ENTER YOUR CHOICE; 1, 2, 3 OR 4"
6955 A$=INKEY$:IF A$="" THEN 6955
6960 IF A$<>"1" AND A$<>"2" AND A$<>"3" AND A$<>"4" THEN 6950
6970 IF A$="1" THEN GOSUB 7500
6980 IF A$="2" THEN GOSUB 7920
6990 IF A$="3" THEN GOSUB 7030
7000 IF A$="4" THEN GOTO 6170
7010 GOTO 6890
7020 COLOR 7,0:KEY OFF:CLS
7030 REM *****************PUMPING STATION GENERAL INFORMATION *****************
7040 CLS:LOCATE 1,18:COLOR 14,3:PRINT"P U M P I N G   S T A T I O N   O U T P U T   S E S S I O N
7050 LOCATE 7,18:COLOR 14,3:PRINT"A. GENERAL INFORMATION ABOUT THE PROJECT:
7060 LOCATE 9,8:COLOR 15,0:PRINT"      PROJECT NAME:
7070 LOCATE 11,8:PRINT "          LOCATION:
7080 LOCATE 13,5:PRINT "EXPECTED STARTING DATE: MONTH(mm)=      YEAR(yyyy)="
7090 LOCATE 8,4:PRINT CHR$(201):FOR I=1 TO 70:LOCATE 8,4+I:PRINT CHR$(205):NEXT I:LOCATE 8,4+I:PRINT CHR$(187)
7100 LOCATE 14,4:PRINT CHR$(200):FOR I=1 TO 70:LOCATE 14,4+I:PRINT CHR$(205):NEXT I:LOCATE 14,4+I:PRINT CHR$(188)
```

```
7110 LOCATE 8,4:FOR I=1 TO 5:LOCATE 8+I,4:PRINT CHR$(186):NEXT
I
7120 LOCATE 8,75:FOR I=1 TO 5:LOCATE 8+I,75:PRINT
CHR$(186):NEXT I
7130 LOCATE 9,29:COLOR 15,0:PRINT PRJCT$
7140 LOCATE 11,29:PRINT PLACE$
7150 LOCATE 13,41:PRINT STMONTH
7160 LOCATE 13,60:PRINT STYEAR
7170 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE ....."
7180 A$=INKEY$:IF A$="" THEN 7180
7190 COLOR 7,0
7200 REM *************** PUMPING STATION PRIMARY FACTORS
***********************
7210 CLS:COLOR 14,3:LOCATE 1,20:PRINT"P U M P I N G  S T A T I O
N  O U T P U T  S E S S I O N
7220 LOCATE 4,4:COLOR 14,3:PRINT"B. PRIMARY FACTORS:
7230 LOCATE 3,4:COLOR 15,1:PRINT"PROJECT: ";PRJCT$
7240 LOCATE 6,4:COLOR 15,0:PRINT"FACTOR            FACTOR
DESCRIPTION                VALUE
7250 LOCATE 7,6:PRINT"#
7260 FOR I=1 TO 5
7270 LOCATE 8+2*I,5:PRINT I
7280 NEXT I
7290 LOCATE 10,14:PRINT"NORMAL PUMPING CAPACITY (m3/HOUR)
7300 LOCATE 12,14:PRINT"NORMAL OPERATING HEAD (m)
7310 LOCATE 14,14:PRINT"TYPE OF PUMPING STATION
(FORWARD=1  BOOSTER=0)
7320 LOCATE 16,14:PRINT"CRANE CAPACITY (TON)
7330 LOCATE 18,14:PRINT"EXPECTED PROJECT DURATION (MONTH)
7340 LOCATE 5,3:PRINT CHR$(201):FOR I=1 TO 70:LOCATE
5,3+I:PRINT CHR$(205):NEXT I:LOCATE 5,3+I:PRINT CHR$(187)
7350 LOCATE 19,3:PRINT CHR$(200):FOR I=1 TO 70:LOCATE
19,3+I:PRINT CHR$(205):NEXT I:LOCATE 19,3+I:PRINT CHR$(188)
7360 LOCATE 5,3:FOR I=1 TO 13:LOCATE 5+I,3:PRINT
CHR$(186):NEXT I
7370 LOCATE 5,74:FOR I=1 TO 13:LOCATE 5+I,74:PRINT
CHR$(186):NEXT I
```

```
7380 LOCATE 5,11:FOR I=1 TO 13:LOCATE 5+I,11:PRINT
CHR$(186):NEXT I
7390 LOCATE 5,64:FOR I=1 TO 13:LOCATE 5+I,64:PRINT
CHR$(186):NEXT I
7400 LOCATE 8,3:PRINT CHR$(204):FOR I=1 TO 70:LOCATE
8,3+I:PRINT CHR$(205):NEXT I:LOCATE 8,3+I:PRINT CHR$(185)
7410 LOCATE 5,11:PRINT CHR$(203):LOCATE 5,64:PRINT
CHR$(203):LOCATE 8,11:PRINT CHR$(206):LOCATE 8,64:PRINT
CHR$(206):LOCATE 19,11:PRINT CHR$(202):LOCATE 19,64:PRINT
CHR$(202)
7420 LOCATE 10,66:COLOR 15,0:PRINT CAPACITY
7430 LOCATE 12,66:PRINT HEAD
7440 LOCATE 14,66:PRINT TYPE
7450 LOCATE 16,66:PRINT CRANE
7460 LOCATE 18,66:PRINT DUR
7470 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE ....."
7480 A$=INKEY$:IF A$="" THEN 7480
7490 COLOR 7,0
7500 REM *************** PUMPING STATION ESTIMATED TENDER
PRICES ***************
7510 CLS:COLOR 14,3:LOCATE 1,20:PRINT"P U M P I N G  S T A T I O
N  O U T P U T  S E S S I O N
7520 LOCATE 4,4:COLOR 14,3:PRINT"C. ESTIMATED TENDER PRICE:"
7530 LOCATE 3,4:COLOR 15,1:PRINT"PROJECT: ";PRJCT$:LOCATE
3,53:PRINT"CONST. DATE: ";STMONTH;"/";STYEAR
7540 COLOR 15,0:LOCATE 5,16:FOR I=1 TO 60:LOCATE 5,16+I:PRINT
CHR$(205):NEXT I
7550 LOCATE 7,16:FOR I=1 TO 60:LOCATE 7,16+I:PRINT
CHR$(205):NEXT I
7560 LOCATE 9,4:FOR I=1 TO 72:LOCATE 9,4+I:PRINT
CHR$(205):NEXT I
7570 LOCATE 12,4:FOR I=1 TO 72:LOCATE 12,4+I:PRINT
CHR$(205):NEXT I
7580 LOCATE 15,4:FOR I=1 TO 72:LOCATE 15,4+I:PRINT
CHR$(205):NEXT I
7590 LOCATE 9,4:FOR I=1 TO 5:LOCATE 9+I,4:PRINT CHR$(186):NEXT
I
```

```
7600 LOCATE 5,16:FOR I=1 TO 9:LOCATE 5+I,16:PRINT
CHR$(186):NEXT I
7610 LOCATE 8,22:PRINT"2        2.5        3        3.5        4
7620 FOR J=28 TO 64 STEP 12:LOCATE 7,J:FOR I=1 TO 7:LOCATE
7+I,J:PRINT CHR$(186):NEXT I:NEXT J
7630 LOCATE 5,76:FOR I=1 TO 9:LOCATE 5+I,76:PRINT
CHR$(186):NEXT I
7640 LOCATE 9,4:PRINT CHR$(201):LOCATE 12,4:PRINT
CHR$(204):LOCATE 15,4:PRINT CHR$(200)
7650 LOCATE 5,16:PRINT CHR$(201):LOCATE 5,76:PRINT
CHR$(187):LOCATE 7,16:PRINT CHR$(204):LOCATE 7,76:PRINT
CHR$(185):LOCATE 9,76:PRINT CHR$(185):LOCATE 12,76:PRINT
CHR$(185):LOCATE 15,76:PRINT CHR$(188)
7660 FOR I=16 TO 64 STEP 12:LOCATE 15,I:PRINT CHR$(202):NEXT I
7670 FOR I=28 TO 64 STEP 12:LOCATE 7,I:PRINT CHR$(203):NEXT I
7680 FOR I=9 TO 12 STEP 3:FOR J=16 TO 64 STEP 12:LOCATE I,J:PRINT
CHR$(206):NEXT J:NEXT I
7690 LOCATE 6,30:PRINT"AVERAGE ANNUAL PRICE ESCALATION
(%)":COLOR 2,0:LOCATE 6,66:PRINT"*":COLOR 7,0
7700 COLOR 2,0:LOCATE 10,14:PRINT"**":LOCATE 13,13:PRINT
"***":COLOR 15,0
7710 LOCATE 11,5:PRINT"UNIT PRICE":LOCATE 14,5:PRINT"TOTAL
PRICE"
7720 COLOR 2,0:LOCATE 17,4:PRINT"* AVGE. ANNUAL PRICE
ESCALATION OF INSTALLED PUMPING STATION SINCE JAN/1993."
7730 LOCATE 18,3:PRINT"** ESTIMATED UNIT PRICE OF INSTALLED
PUMPING STATION (";CHR$(241);" 0 RO/ m3/hR)"
7740 LOCATE 19,2:PRINT"*** ESTIMATED TOTAL PRICE OF TENDER
(";CHR$(241);" 0 RO)":COLOR 7,0
7750 REM *************PUMING STATION FILLING THE TABLE OF
FINAL ANSWER*******
7760 COLOR 3,0
7770 TIMDIFF=(STYEAR-1993)+((STMONTH-1)/12)    ' CALCULATING
TIME DIFFERENCE
7780 COL=5
7790 FOR I=2 TO 4 STEP .5
7800 COL=COL+12
7810 ESCPRICE=PRICE*(1+(I/100))^TIMDIFF
7820 LOCATE 14,COL:PRINT USING "##,###,###";ESCPRICE
```

```
7830 NEXT I
7840 COL=7
7850 FOR I=2 TO 4 STEP .5
7860 COL=COL+12
7870 ESCRATE=(PRICE/CAPACITY)*(1+(I/100))^TIMDIFF
7880 LOCATE 11,COL:PRINT USING "#,###.##";ESCRATE
7890 NEXT I
7900 LOCATE 21,6:COLOR 11,14:PRINT"PRESS ANY KEY TO
CONTINUE .....":A$=INKEY$:IF A$="" THEN 7900
7910 COLOR 7,0:RETURN
7920 REM ****************** PUMPING STATION PRINT OUTPUT
******************
7930 LPRINT"        P U M P I N G  S T A T I O N  O U T P U T  S E S S
I O N":LPRINT:LPRINT:LPRINT:LPRINT
7940 LPRINT"A. GENERAL INFORMATION ABOUT THE PROJECT:
7950
LPRINT"_______________________________________________________
_"
7960 LPRINT"        PROJECT NAME:";PRJCT$
7970 LPRINT"            LOCATION:";PLACE$
7980 LPRINT"EXPECTED STARTING DATE:     MONTH:";STMONTH;"
YEAR:";STYEAR
7990
LPRINT"_______________________________________________________
_"
8000 LPRINT:LPRINT:LPRINT:LPRINT
8010 LPRINT"B. PRIMARY FACTORS:"
8020
LPRINT"_______________________________________________________
_"
8030 LPRINT"      FACTOR                           VALUE
8040
LPRINT"_______________________________________________________
_"
8050 LPRINT"1. NORMAL PUMPING CAPACITY
(m3)";TAB(51);CAPACITY
8060 LPRINT"2. NORMAL OPERATING HEAD (m)";TAB(51);HEAD
8070 LPRINT"3. TYPE OF PUMPING STATION  (FORWARD=1
BOOSTER=0)";TAB(51);TYPE
```

```
8080 LPRINT"4. CRANE CAPACITY (TON)";TAB(51);CRANE
8090 LPRINT"5. EXPECTED PROJECT DURATION
(MONTH)";TAB(51);DUR
8100
LPRINT"______________________________________________________
   "
__
8110 LPRINT:LPRINT:LPRINT:LPRINT
8120 LPRINT"C. ESTIMATED TENDER PRICE:"
8130
LPRINT"______________________________________________________
      "
_____
8140 LPRINT" ANNUAL PRICE *          UNIT RATE **     TOTAL
PRICE ***
8150 LPRINT"ESCALATION (%)           (RO/ m3/hr)        (RO)
8160
LPRINT"______________________________________________________
      "
_____
8170 TIMDIFF=(STYEAR-1993)+((STMONTH-1)/12)
8180 DIM ESCRATE(5),ESCPRICE(5)
8190 FOR I=2 TO 4 STEP .5
8200 ESCPRICE(I)=PRICE*(1+(I/100))^TIMDIFF
8210 ESCRATE(I)=ESCPRICE(I)/CAPACITY
8220 LPRINT TAB(7);I;TAB(30);ESCRATE(I);TAB(48);ESCPRICE(I)
8230 NEXT I
8240
LPRINT"______________________________________________________
      "
_____
8250 LPRINT
8260 LPRINT"  * AVERGAE ANNUAL PRICE ESCALATION OF
INSTALLED PUMPING STATION SINCE JAN/1993"
8270 LPRINT" ** ESTIMATED UNIT PRICE OF INSTALLED PUMPING
STATION (+/- 0 RO/ m3/hr)"
8280 LPRINT"*** ESTIMATED TOTAL PRICE OF TENDER (+/- 0 RO)"
8290 RETURN
```

APPENDIX - F

CCES TESTING TABLES

TESTING TABLE FOR THE PIPELINE MODEL

OBS #	ACTUAL COST (RO)	ESTIMATED COST (RO)	ERROR (%)
1	60182	87505	45
2	170474	212283	24
3	1596015	1476193	7
4	534702	814582	52
5	289588	280312	3
6	305231	307078	0
7	563083	459978	18
8	594211	593371	0
9	1711391	1408522	17
10	602246	586046	2
11	1380005	1311239	5
12	1592028	1473963	7
13	24813	36772	48
14	17007	17271	1
15	1820367	1767402	3
16	1329350	1261895	5
17	402099	336103	16
18	448428	413766	8
19	1692993	1642827	3
20	456362	463012	1
21	401319	393491	2
22	145579	154937	6
23	538843	768894	42
24	283006	279626	1
25	218395	195866	10
26	266238	216508	18
27	76989	81577	6
28	57866	44188	23
29	87102	75326	14
30	678764	785810	16
31	636739	939403	48
32	5654845	5505981	3
33	6106045	6479669	6

TESTING TABLE FOR THE RESERVOIR MODEL

OBS #	ACTUAL COST (RO)	ESTIMATED COST (RO)	ERROR (%)
1	957350	946552	15
2	346616	343108	3
3	222930	217271	11
4	1944830	2027646	4
5	60997	77466	27
6	63031	75185	19
7	427374	469594	10
8	458956	431253	6
9	101336	79042	22
10	134780	152948	13
11	112294	75185	33
12	2165490	2084082	4

REFERENCES

1. Adrian, J. J.; Construction Estimating: An Accounting Approach; Englewood Cliffs: Prentice Hall, Inc.; 1982.

2. Akeel, N. F.; A Database Tool for statisticallv Based Construction Estimate; Ann Arbor: UMI; 1989.

3. Albright, S. Christian; Statistics for Business and Economics; New York: Macmillan; 1987.

4. Collier; K.; Estimating Construction Cost: A conceptual Approach; Reston: Prentice Hall Company; 1984.

5. Collier; K.; Fundamentals of Construction Estimating and Cost Accounting with Computer Applications; Englewood Cliffs: Prentice Hall, Inc.; 1987.

6. Ferry, Douglas J, and Petter S. Brandon; Cost Planning of Buildings; Oxford: BSP Professional Books; 1991.

7. Hackney, John W.; Control and Management of Capital Projects; McGraw Hill, Inc.: New York; 1992.

8. Karshenas, Saeed, and Zafar S. Yousuf; "Predesign Estimate of Elevator Cost in Multistory Buildings"; **AACE Transaction**; 1985; pp. B.8.1 to B.8.4.

9. Kemner, William F., and John Abraham, and Jay Palmisano; "Computerized Cost Model for Superfund Technologies"; **AACE Transaction**; 1987; pp. C.4.1 to C.4.12.

10. Manzanera, Ignacio; **Cost Estimating**; Saudi ARAMCO publication: Dhahran; 1991.

11. Mlakar, Paul F., and Larry M. Bryant; "Direct Range Cost Estimating"; **AACE Transaction**; 1990; pp. K.4.1 to K.4.3.

12. Ntuen, Celestine A., and Arup K. Mallik; "Applying Artificial Intelligence to Project Cost Estimating"; **Cost Engineering**; May 5, 1987; pp. 8 to 13.

13. Omani American Joint Commission (OAJC); **Feasibility Studies for Third Five Plan System Improvements for Capital Area Water Distribution**; OAJC publication: Muscat; 1986.

14. Raftery; J.; "The State of Cost Price Modelling in the UK Construction Industry: A Multicriteria Approach"; **Building Cost Modelling and**

Computers by P. S. Brandon; E. & F. N. Spon; London; 1987.

15. Rounds, Jerald L.; "Expert System Potential as a Cost Engineering Tool; AACE Transaction; 1986; pp. H.5.1 to H.5.5.

16. Shepherd, J. C.; Database Management: Theory and Application; Homewood: Irwin; 1990.

17. Steel, E. W., and Terence J. McGhee; Water Supply and Sewerage; New York: McGraw Hill Co., Inc.; 1979.

18. Stewart, Rodney D.; Cost Estimating; New York: John Wiley & Sons, Inc; 1991.

19. Suarez, John J.; "Conceptual Estimating"; AACE Transaction; 1986; pp E.1.1 to E.1.5.

20. Water Research Center; Cost Information for Water Supply and Sewage Information; Medmenham: WRC; 1977.

BIBLIOGRAPHY

1. Al-alawi, Muhsin; Contractor Prequalification: A computerized Model for Public Projects in Bahrain; Dhahran: KFUPM Press; 1991.

2 Aitah, Redha Amin; Performance Study of the Lowest BidderBid Awarding ystem in Government Projects - Saudi Arabia; Dhahran KFUPM Press; 1988.

3. Barry, Ronald A.; "Cost Estimating and the Personal Computer"; AACE Transactions; 1987; pp. B.2.1 to B.2.7.

4. Dielman, Terry E.; Applied Regression Analysis for Business and Economics; Boston: PWS-KENT; 1991.

5. Enders, Bernd, and Bob Petersen; Basic Primer for the IBM PC and XT; New York: Plume Waite; 1984.

6. Gallagher, William E., and Thomas C. Ponder, and Juan M. Castro; "Parametric Estimating Factors for Demolition Costs"; AACE Transactions; 1987; pp. C.2.1 to C.2.6.

7. Gunst, Richard, and Robert Mason; Regression Analysis and its

Application; New York: Marcel Dekker, Inc.; 1980.

8.Hackney, John W., and Kay Hudson, and Lasely Gasperow; "Parametric Cost Estimating a Guide"; AACE Transactions; 1987; pp C.3.1 to C.3.7.

9. Hollman, John K., and Larry Dysert; "Development of Conceptual Estimating Support Systems at Kodak"; AACE Transactions; 1989; pp. B.3.1 to B.3.8.

10. Korbitz, William E.; Modern Management of Water and Wastewater Utilities; Garland STPM Press: New York; 1981.

11. Mansfield, G. L.; Bidding and Estimating Procedures for Construction; Reston: Publishing Company; 1983.

12. Rounds, Jerald L.; "Integrated Software Solutions to Cost Engineering Problems"; AACE Transactions; 1985; pp. G.2.1 to G.2.5.

13. Statistical Graphics Corporation; STATGRAPHICS Reference and Operation Manuals; Singapore: STSC; 1991.

14.Touran, Ali, and Demtrios Zikes; "Conceptual Estimator: A computer Program for Residential Estimating"; **AACE Transactions**; 1990; pp.K.5.1 to K.5.3.